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CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE

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Pierre PICARD
Kili C. WANG

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DEPARTEMENT D'ECONOMIE

Route de Saclay
91128 PALAISEAU CEDEX
(33) 1 69333033
http://www.economie.polytechnique.edu/
mailto:chantal.poujouly@polytechnique.edu

Insurance Fraud through Collusion between Policyholders and Car Dealers: Theory and Empirical Evidence

Pierre Picard* Kili C. Wang†

Abstract

We analyze, from theoretical and empirical standpoints, how insurance distribution channels may affect fraud when policyholders and service providers collude. The empirical analysis focuses on the Taiwan automobile insurance market. Striking forms of claims manipulation exist in this market: opportunistic policyholders tend to manipulate claim dates to reduce the burden of deductibles and to take advantage of the bonus-malus mechanism. We focus our attention on the role of dealer-owned agents (DOAs), since they have informational and bargaining advantages when faced with insurers and may be tempted to encourage collusion between their car repairers and policyholders. We develop an optimal contract model with claim auditing, where contracts are sold either through DOAs or through standard independent agents, and where policyholders and car repairers may collude to manipulate claims. We also use a database from the largest Taiwanese insurance company to test for the relevance of theoretical predictions. In particular, we verify that fraud occurs through the postponing of claims to the end of the policy year, possibly by filing one single claim for several events, and we show that the fraud rate is larger among policyholders who purchase insurance through the DOA channel than among other policyholders.

*Department of Economics, Ecole Polytechnique. Email: pierre.picard@polytechnique.edu. Pierre Picard acknowledges financial support from Investissements d'Avenir (ANR-121-IDEX-0003/Labex ECODEC).

†Department of Insurance, Tamkang University, Taiwan. Email: kili@mail.tku.edu.tw.

1 Introduction

Claims fraud is widely considered to be an important source of inefficiency in insurance markets, and deterring or detecting fraud is of crucial importance for the insurance industry. In particular, the collusion between policyholders and service providers (e.g., car repairers or health care providers) facilitates the falsification of claims, and it is one of the most important factors that encourage fraudulent practices.[1] This is similar to other fraud schemes in vertical relationships, such as discount fraud and warranty fraud, which are facilitated by retailers.[2,3] Such frauds are instances of customer misbehavior that involve collusion with retailers or frontline employees at the expense of producers and, ultimately, of honest customers.[4]

In this paper, we further analyze how the collusion between policyholders and service providers facilitates fraud. Our empirical focus is on the Taiwan automobile insurance market and on the role of car dealer-owned insurance agents (DOAs) in this market. In Taiwan, a large percentage of automobile insurance contracts are sold through DOAs. Thus, DOAs sell not only cars, but also automobile insurance to their clients, and furthermore most of them own an auto repair shop. Understandably, the multi-faceted activity of DOAs and their long-term connection with car owners favor the creation of a mutually advantageous

[1] The fact that the alliance between patients and physicians may lead to health care overspending is well documented in the health economics literature on ex-post moral hazard. Although medical ex-post moral hazard is not *stricto sensu* a fraudulent behavior, it highlights the importance of the policyholder-service provider coalition, and how this coalition may jeopardize the efficiency of social or private risk-sharing mechanisms. See Alger and Ma (2003) on the deterrence of collusion between policyholders and service providers when some providers are collusive and others are honest. When there is a risk of collusion, the contractual relationship between insurers and service providers may improve the efficiency of resource allocation, for instance through affiliated service provider networks, such as managed care organizations for health insurance (e.g., HMO and PPO in the USA) or Direct Repair Programs (DRP) for automobile insurance. See Gal-Or (1997) and Ma and McGuire (1997, 2002) on managed health care and Bourgeon et al. (2008) on affiliated service provider networks.

[2] Discount fraud exploits the special discounts that companies may offer under particular circumstances, for instance when discounted products are used for a specific purpose, e.g., educational use for softwares. Although large scale discount fraud perpetrated by criminal enterprises does exist (in 2010, defrauders were sentenced to five years in prison and ordered to pay Microsoft $20 million in restitution for discount fraud), it probably remains exceptional. Small scale discount fraud involving collusion between retailers (who may guarantee the legitimacy of the discount) and opportunistic purchasers is probably much more widespread, although it is difficult to evaluate its cost.

[3] There are several patterns of warranty fraud (or service abuse). One of them exploits certain warranty policies that allow the end client to receive replacement parts for a product before returning the defective components, thus without verification that they were original products. Warranty fraud also occurs when a service provider, e.g., a car repairer, replaces a defective part with a new spare part and triggers the producer's warranty, although the defective part was not original and thus was not protected by the warranty.

[4] See Harris and Daunt (2013) on managerial strategies under the risk of customer misbehavior. Murthy and Djamaludin (2002) survey the literature on new product warranty. Insufficient maintenance effort by buyers and inadequate behavior of retailers are at the origin of a double moral hazard problem in warranty management. This is a particular case of transaction costs induced by the delegation of services to retailers; see Rey (2003) for an introductory survey.

policyholder-DOA alliance.

With the Taiwan case in mind, we will analyze the interaction between policyholders, car repairers and insurers when policyholders and repairers may collude to manipulate claims and insurers attempt to detect fraud through claims auditing. To do so, we will first elaborate a model that shows why deductible contracts and the bonus-malus system may provide incentives to falsify claims, and also why DOAs may lead to higher fraud rates. In short, claims auditing is all the more costly when collusion is more difficult to detect, which is particularly the case for DOAs. In addition, should irregularities be detected by the insurer, DOAs have greater bargaining power than standard insurance agents because their market share (per agent) is larger, and they have a more captive clientele base, which they can credibly redirect toward another insurer. This may deter insurers from enforcing penalties against them, hence higher equilibrium fraud rates when claims are filed through DOAs than through standard insurance agents. This is reinforced in the case of deductible contracts, because deductibles weaken the insurers' incentives to monitor claims. Furthermore, the policyholders who intend to renew their contracts with the same insurer at the end of the policy year are even more incentivized to defraud because of specificities of the Taiwanese bonus-malus system.

This will lead us to an empirical analysis based on a database of automobile physical damage insurance obtained from the largest insurance company in Taiwan. This data includes all of the policyholders who have filed a claim in 2010, amounting to nearly 11,000 files. Our results sustain the prediction that fraud is greater when insurance policies have been sold through DOAs than through other distribution channels, and also that deductibles stimulate fraud.

This can be likened to the conclusions of Dionne and Gagné (2001). Using data from Québec, they showed that the amount of the deductible is a significant determinant of the reported loss when no other vehicle is involved in the accident which led to the claim, and thus when the presence of witnesses is less likely. Miyazaki (2009) also focuses on the effect of deductibles on insurance fraud. He shows through an experimental study that higher deductibles result in a weaker perception that claim padding is an unethical behavior, and thus in a larger propensity toward fraud. In this paper, we link deductibles to the falsification of the number of claims and of the claim date (filing one claim for two accidents and /or postponing claims to the last month of the policy year to take advantage of specific features of the Taiwanese bonus-malus system). Furthermore, we focus attention on the role of the policyholder-car repairer coalition and provide empirical evidence on the impact of such a coalition on the intensity of insurance fraud.

The remaining part of the paper is organized as follows. Section 2 provides further motivation for our analysis. We introduce some factual observations that should convince the reader that there is a significant degree of claim manipulation in the Taiwanese car insurance market, and we describe regular fraud patterns. Section 3 develops our theoretical model to include claims auditing and the policyholder-car repairer coalition. Section 4 describes the data. Section 5 presents our empirical approach and discusses our results. Section 6 concludes. Complementary developments and mathematical proofs are in the Appendix.

2 Motivation

DOAs hold a substantial market share in the Taiwan automobile insurance market. For the insurance company that provides the base of our empirical analysis, 50.78% of vehicle damage insurance is sold through DOAs.[5] Furthermore, DOAs own the list of their customers, which increases their bargaining power when they negotiate contractual deals with insurance companies or when insurers monitor claims. An insurer who discovers a claim manipulation by a DOA may indeed hesitate to take retaliatory actions because of this strategic advantage of DOAs, who can choose to switch to another insurer.[6] In addition, DOAs also act as car repairers, and this position provides them with an informational advantage: establishing that a claim has been falsified is particularly difficult and costly when it has been filed through a DOA.

Our study is also related to the specific forms of automobile insurance fraud in Taiwan.

[5] More precisely, 67.52% of type A contracts, 84,19% of type B contracts, and 43.71% of type C contracts are sold by DOAs. Read further for additional information on the three types of insurance contracts in Taiwan.

[6] On average, DOAs sell more policies than other agents (three times more on average and considerably more for the largest DOAs), and their market power is particularly significant for deductible contracts. They are independent agents, and, as emphasized by Mayers and Smith (1981), this status gives them more discretion in claim administration (e.g., they may intercede on behalf of their customers at the claim settlement stage) because they can credibly threaten to switch their business from one insurer to another. Actually, DOAs provide comparatively less stable customers to insurers than other insurance agents, with continuation rates (i.e., the fraction of customers who keep purchasing insurance from the same insurer one year after the other) which are about sixty percent for DOAs and seventy to eighty percent for other insurance agents.

Li et al. (2013) have observed that a large proportion of automobile insurance claims are filed during the last months of the policy year. This is confirmed by our own database. Figure 1 presents the percentage distribution of claims and the average cost of claims (in hundred US dollars) over the twelve policy months. The heavy concentration of claims in the last month of the policy year is striking. Policy years and calendar years do not coincide and, as shown in Figures 2 and 3, the concentration of claims during the last months of the policy year is compatible with seasonal fluctuations in the number of claims over the calendar year, with peaks during vacation months (January, March, July and December). In addition, the average claim amount slightly decreases in the final policy months. Li et al. (2013) interpret this phenomena as a "premium recouping effect": some policyholders without accident during the previous months tend to file false smaller claims during the last month of the policy year in order to recoup a part of their premium. They might do so to express their feeling that they have been unfairly treated by the insurance company. Whatever the interpretation we may have in mind, this distribution of claims over time strongly suggests that claim filing is manipulated by a significant number of policyholders.

(Insert Figures 1,2 and 3 here)

Some factual information is needed to identify the factors that may lead policyholders to manipulate claims. There are three different types of automobile physical damage insurance contracts in Taiwan: types A, B and C. Type A and B contracts cover all kinds of collision and non-collision losses, with more exclusions for B than for A,[7] while type-C contracts only cover the damages incurred in a collision involving two or more vehicles. Contracts also differ in terms of indemnity: Type A contracts offer low coverage with a deductible, type B contracts may be purchased with or without deductible, and finally type C contracts provide full coverage without deductible. Claims are per accident, with a specific deductible for each claim. The change in premium is ruled by a bonus-malus system when policyholders renew their contracts with the same insurance company, with a no-claim discount and an increase in premium proportional to the number of claims, without reference to their severity. The policyholders who switch to another insurance company bargain with this company about the new starting point of the bonus-malus record

[7] Type B contracts cover all the areas of type-A contracts, except the non-collision losses caused by intentional damage, vandalism, and any unidentified reasons.

In this setting, opportunist policyholders may take advantage of manipulating claims for several reasons. According to the premium recouping interpretation of Li et al. (2013), defrauders are more likely to be among the policyholders who do not plan to keep a long term relationship with the same insurance company if, on average, such policyholders feel a lower moral cost of defrauding.[8] In our empirical analysis, this will lead us to define a "recoup group" RG that includes the policyholders who have not renewed their contract more than one year after the policy year under consideration.[9]

The bonus-malus system and the per-claim deductibles also provide incentives to defraud. Firstly, the claims filed during the last month of policy year t are not registered in the bonus-malus record of year $t+1$ (they will be taken into account in the premium paid in year $t+2$), and consequently, the policyholders who plan to renew their contract with the same insurer may be incited to postpone their claim to the last policy month, in order to delay the increase in premium.[10] Secondly, since the bonus-malus record depends on the number of claims and not on their severity, policyholders may be prompted to file one unique claim for two accidents, should a second accident occur. This is even more profitable in the case of deductible contracts, since deductibles are per-claim: the strategy that consists of postponing the first claim and merging any other accident with the first one within a unique claim yields full coverage for the part of the year that follows the first accident. Type A and B contracts are particularly subject to this kind of claims manipulation, because they include coverage for losses other than those associated with the collision between two cars. In our empirical analysis, the set of policyholders who renew their contract with the same insurer will be called the "suspicious group" SG because of this incentive to manipulate the bonus-malus system, with subgroups $SG1$ and $SG2$ for no-deductible and deductible contracts, respectively.

If we conjecture that some claims filed in the last policy month correspond in fact to postponed claims with the cumulated losses of two events, then we should expect that the ratio of "the average cost of first claims" over "the average cost of all claims" (hereafter

[8] It is well known that insurance fraud is often associated with the feeling that the insurance company is unfair; see Fukukawa et al. (2007), Miyazaki (2009) and Tennyson (1997, 2002). The premium recouping phenomenon could reflect a kind of resentment against insurers, particularly from policyholders who have not filed any claim during the policy year.

[9] Because of the bonus-malus system (see below), the policyholders who renew their contract only one year have the same incentive to defraud as the policyholders who switch insurers at the end of the policy year.

[10] In addition, the bonus-malus system forgives the first accident for drivers who have had no other accidents for three years, which provides an even larger manipulation gain.

called the *first claim cost ratio*) should increase during this month. Note however that this prediction could also be interpreted as the outcome of a moral hazard mechanism: this would be the case if a first accident made drivers more cautious, and thus they have less severe accidents should a second accident occur during the same policy year. To disentangle these two explanations, we may consider type C contracts as a benchmark to isolate the moral hazard effect, since claims manipulation is unlikely for such a contract.[11] Figure 4 confirms our intuition: the first claim cost ratios for $SG1$ and $SG2$ significantly jump in the last month, and this is not the case for type C policies.

(Insert Figure 4 here)

At this stage, we may come back to the part played by DOAs. Figure 5 confirms that DOAs may favor the manipulation of claims. While the claims filed by the policyholders of the two suspicious groups, $SG1$ and $SG2$, are significantly concentrated in the last policy month, this pattern is even more obvious for the policyholders of each subgroup that have purchased insurance from DOAs. Figure 5 also shows that the last policy month pattern is much less obvious in the benchmark group, which includes those policyholders who are covered by no-deductible contracts and who have not renewed their contract with the same insurance company at the end of the policy year.

(Insert Figure 5 here)

3 The model

3.1 Setting

We consider an economy with a competitive insurance market, in which automobile insurance can be purchased either through car dealers who act as insurance agents (DOAs) or through independent insurance agents. Car dealers also own auto repair shops. Accidents may be minor or serious, with repair costs ℓ and 2ℓ whatever the car repairer, for minor and serious

[11] Type C contracts only cover the risk of collision. Thus, their claims involve a third party, which makes manipulation difficult.

accidents respectively, and also an uninsurable loss ε per accident.[12] Insurance policies consist of a premium P and possibly a deductible d for each accident.[13] Insurance pricing includes constant proportional loading σ, and insurers may offer different policies through car dealers and through other distribution channels.

Each individual may suffer from 0, 1 or 2 accidents during the period covered by the insurance contract.[14] Let π_1 and π_2 be respectively the probability of 1 and 2 accidents, with $0 < \pi_1+\pi_2 < 1$. Each accident is minor with probability q_m and serious with probability q_s, with $q_m + q_s = 1$. There are two types of individuals with the same initial wealth w: type 1 has a smaller degree of absolute risk aversion than type 2. Let w_f be the individual's final wealth. $u_h(w_f)$ denotes the type h von Neumann-Morgenstern utility function (with $h = 1$ or 2), and we assume $u_h' > 0$ and $u_h'' < 0$, and

$$-\frac{u_1''(w_f)}{u_1'(w_f)} < -\frac{u_2''(w_f)}{u_2'(w_f)},$$

for all w_f. Let λ_h be the proportion of type h individuals, with $\lambda_1 + \lambda_2 = 1$. Car repairers are risk neutral.

We also assume that individuals have differentiated preferences between purchasing insurance through a car dealer or through an independent agent. In particular, individuals who

[12] Assuming that the insurable costs of serious accidents exactly double those of minor accidents simplifies the notations of the model. We could more generally assume than serious accidents cost more than minor accidents. The repair shop market is competitive, so that policyholders can let their car be repaired at competitive price ℓ or 2ℓ whatever the insurance distribution channel. The uninsurable loss ε corresponds to earnings losses, time value, daily life disruption or stress incurred in the case of an accident. This loss does not play a significant role in our theoretical analysis, but it makes it possible for some individuals to choose a deductible contract while others prefer a full coverage contract (in what follows, the type 1 and 2 individuals respectively), which will fit our empirical analysis of the Taiwan automobile insurance market. The fact that the uninsurable loss does not depend on the size of the accident simply reflects notational simplicity. More generally, we could assume that the individuals' wealth is affected simultaneously by the insurable cost of accidents and by an uninsurable correlated background risk.

[13] The fact that deductibles are per accident follows the usual practice of car insurance companies (of course not only in Taiwan), although it does not correspond to an optimal insurance contract design. This feature of automobile insurance probably reflects the increase in transaction costs that would be induced by aggregate deductibles over the whole period covered by the contract. We exclude overcoverage, such as because of moral hazard, and thus we have $d \geq 0$. For simplicity, we assume that the deductible is the same for the first and second claims. In Taiwan, second claims have larger deductibles than the first one that occurred during the same policy year. This increase in the level of deductible may be viewed as an incentive device in a moral hazard setting (see Li et al, 2007). The present model could be extended to a setting where deductibles would differ between first and second claims, without affecting our qualitative conclusions.

[14] Thus, we assume that policyholders cannot have more than two accidents during the policy year. A possible justification for this assumption is that three accidents or more would reveal an abnormal behavior on the part of drivers that would lead insurers to deny the renewal of the contract at the end of the policy year, which would induce large transaction costs to the policyholder. If two accidents occur, then the policyholder would make unusual effort (e.g., greatly reducing the use of his car) that would allow him to avoid any additional accidents during the same policy year.

have high search costs may prefer to purchase insurance through car dealers because often purchasing a new car goes together with taking out a new insurance policy. This is modelled as in a Hotelling game. Both types of individuals are uniformly located on the interval $[0,1]$. A representative DOA and another representative independent insurance agent are located at the extremities of the $[0,1]$ segment: the DOA is at $x = x_D = 0$ and owns a repair shop, while the the other distribution channel is at $x = x_A = 1$.

Purchasing insurance entails a search disutility which is proportional at rate t to the distance covered to 0 and 1 according to the distribution channel. Thus, the expected utility of a type h customer located at $x \in [0,1]$ with contract (P,d) is written as

$$\overline{u}_h(P,d) - t\left|x - x_i\right|,$$

where

$$\overline{u}_h(P,d) \equiv (1-\pi_1-\pi_2)u_h(w-P) + \pi_1 u_h(w-P-d-\varepsilon) + \pi_2 u_h(w-P-2d-2\varepsilon), \quad (1)$$

for $h = 1$ or 2, with $i = D$ if that customer purchases insurance through the representative DOA and $i = A$ if he goes through the other distribution channel.[15]

Type 2 individuals have a larger propensity to purchase insurance coverage than type 1 because they are more risk averse. Because of these differentiated preferences, insurers offer menus of contracts. Let (P_{ih}, d_{ih}) be the insurance contract that is taken out by type h individuals, with $i = A$ or D according to the distribution channel.[16]

3.2 The fraud mechanism

Fraud is analyzed as the behavior of oppportunistic policyholders who delay their claims to the last month of the policy year, with the complicity of a car repairer. We consider a very

[15] We assume that the degree of risk aversion and the preference between the two distribution channels are independently distributed among the population.

[16] In practice, deductibles and premiums do not differ in Taiwan whether the contract is purchased through D or through A. Note however indemnities and premiums may include a less easily observed (or implicit) dimension associated either with delays or conditions in the payment of indemnities. For instance, given the value of time, a longer delay between the filing of the claim and the payment of the indemnity is equivalent to a larger deductible. In this perspective, empirical facts suggest that this delay is shorter for D than for A. In other terms, policyholders may actually benefit from a more generous coverage plan if their contract has been purchased through a dealer-owned agent than through another distribution channel, although the contractual indemnity is the same in both cases.

simple form of the opportunistic policyholder-car repairer collusive game. The policyholder makes a take-it-or-leave-it offer to the car repairer in which he offers to pay a fixed amount G to the repairer and he keeps the residual part of the collusive gain. Because of the bonus-malus system, type 1 and 2 policyholders may commit such a fraud in order to avoid paying a higher premium during the next policy year, and we denote as v the discounted value of the savings in future insurance premiums induced by such a bonus-malus fraud.[17] Only those individuals who plan to renew their contract with the same insurer may profit from such a bonus-malus fraud. We assume that they make up a proportion $\delta \in (0,1)$ of the policyholders (whatever their type). The last month of the policy year will be called the "suspicious period", because filing a claim during this period may be a signal of fraud. Accidents occur during the suspicious period with probability $\mu \in (0,1)$.[18]

We also assume that postponing a minor claim to the suspicious period requires that another minor loss actually occurs during this period, so that the total losses may be presented as the outcome of a single major accident. Policyholders also get an additional advantage from fraud by reducing the retained cost from $2d_{ih}$ to d_{ih}. Thus, if fraud has been committed and is not detected, the collusive gain is $d_{ih} + v$, and it is shared between repairer and policyholder as amounts G and $d_{ih} + v - G$ respectively.

Thus, if a minor accident occurs during the non-suspicious period, then the policyholder may decide not to immediately file a claim for this accident. Two possible cases are then possible.[19] If another minor accident occurs in the suspicious period, then the policyholder may decide to file a single large claim for the two accidents (called a "fraudulent claim" in what follows), which requires collusion with a car repairer. Auditing large claims filed during the suspicious period allows the insurer to detect such instances of fraud. We denote as c_i the cost of an audit when insurance is purchased from $i \in \{D, A\}$. The fact that the car dealer owns the repair shop makes collusion all the easier. Thus, we assume that auditing

[17] In Taiwan, bonus-malus fraud is profitable for the policyholder for two reasons: firstly, because claims filed during the suspicious period will affect the premium with a one-year time lag, and secondly because the bonus-malus record only depends on the number of claims and not on their severity. For simplicity, we here aggregate these financial benefits derived from fraud and we assume that they have a common value for all policyholders.

[18] Thus, $\mu = 1/12$ if accidents are uniformly spread throughout the year.

[19] Bear in mind that in what follows we neglect the possibility of more than two accidents for the same policyholder. We also assume that there are only two types of acccidents (minor or serious) with repair costs of ℓ and 2ℓ, respectively. Thus, we do not contemplate the possibility of presenting, say, a minor accident and a serious accident as an extreme accident with cost 3ℓ. In other words, the falsification of claims only consists of announcing one single serious accident instead of two minor accidents.

claims is more costly (or, put differently, it is more difficult to establish colluders' fraud) when insurance is purchased from D than from A.[20] We thus assume $c_D > c_A$. If no minor accident occurs in the suspicious period (i.e., if no other accident occurred or if it occurred during the non-suspicious period), then the insurer considers that any late claim is invalid and is dismissed.[21]

If a policyholder is caught filing a fraudulent claim through a collusive agreement with the repairer, then he has to pay a fine B, and he does not receive a indemnity, and the repairer pays a fine B'.[22] In practice, when fraud is discovered, the policyholder-repairer coalition has some bargaining power that may allow its members to escape the penalties. This is particularly the case when insurance has been purchased from a DOA, because the latter is in a position to threaten the insurer with redirecting its (presumably large) customer base toward another insurer. This is another reason why deterring fraud may be more difficult when insurance has been taken out through a DOA than through a standard agent. The effects of agents' bargaining power on the enforcement of fraud penalties is analyzed in Appendix 2, and for the sake of presentation simplicity is not taken into account here.

3.3 Fraud-audit interaction

Let $\alpha_{ih} \in [0,1]$ be the fraud rate of type $h \in \{1,2\}$ individuals who purchase inurance from $i \in \{A, D\}$. This is the fraction of type h policyholders who decide not to immediately file a claim when a minor accident occurs in the non-suspicious period, hoping for a future collusive agreement with a car repairer, should another minor accident occur in the suspicious period.[23] Let $\widehat{\pi} = \pi_2/(\pi_1 + \pi_2)$ be the probability of having a second accident, conditionally on the occurence of a first accident in the non-suspicious period.[24] Such an accident will occur in the suspicious period with probability μ, and it will be minor with probability q_m. Thus, if a

[20] For example, in the DOA case, the hidden transfer G may take the form of a promise to purchase a new car in the near future.

[21] This is a somewhat extreme assumption made for the sake of simplicity. A more realistic setting would consist of assuming that the policyholder can pretend to be in good faith. In that case, (depending on the circumstances of the accident) the law of insurance contracts would lead the insurer to consider that the claim is valid or invalid with some probabilities. Our modelling could be extended in this direction without qualitative change to the conclusions.

[22] B and B' may also be interpreted as the litigation costs incurred by the policyholder and the car repairer when fraud is discovered.

[23] We may check that policyholders would not take advantage of colluding with a repairer if a second accident occurs during the non-suspicious period.

[24] For simplicity, we do not condition this probability on the exact date at which the first accident occurs. In other words, we consider the non-suspicious period as a whole.

first minor acccident occurs in the non-suspicious period, then a future collusive agreement with a car repairer will be possible with probability $q_m\mu\widehat{\pi}$. The audit of serious claims in the suspicious period may detect such fraud. These audits are triggered with probability $\beta_{ih} \in [0,1]$.[25] In short, α_{ih} and β_{ih} for $i = A, D$ and $h = 1, 2$ are the policyholder's and insurer's strategies, respectively.

The expected utility of a type h policyholder who does not immediately file a claim after a first (minor) accident in the non-suspicious period is written as[26]

$$\begin{aligned} Eu_{ih}^F &= q_m\mu\widehat{\pi}[(1-\beta_{ih})u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G) + \beta_{ih}u_h(w - P_{ih} - 2\ell - 2\varepsilon - G - B)] \\ &\quad +(1 - q_m\mu\widehat{\pi})[\widehat{\pi}u_h(w - P_{ih} - \ell - d_{ih} - 2\varepsilon) + (1-\widehat{\pi})u_h(w - P_{ih} - \ell - \varepsilon)]. \end{aligned}$$

If the policyholder does not immediately file a claim after a minor accident in the non-suspicious period, he will have the opportunity to defraud (i.e., to file a single large claim in the suspicious period) with probability $q_m\mu\widehat{\pi}$. In that case, either the claim is audited or not, respectively with probabilities β_{ih} and $1-\beta_{ih}$. If there is no audit, then the policyholder receives $d_{ih} + v - G$, which is his share of the collusive deal, in addition to his status quo net wealth $w - P_{ih} - 2d_{ih}$ (i.e., the policyholder's wealth in the case of two accidents without fraud). If there is an audit, then no indemnity is paid by the insurer, and the policyholder pays the fine B and does not recoup his side-payment G. If no fraudulent claim can be filed, then the late claim is dismissed: no insurance indemnity is paid for this claim, and any other accident (which occurs with probability $\widehat{\pi}$) leads to another claim.

If the policyholder immediately files a claim after his first minor accident, then his expected utility (after this first accident) is

$$Eu_{ih}^N = \widehat{\pi}u_h(w - P_{ih} - 2d_{ih} - 2\varepsilon) + (1-\widehat{\pi})u_h(w - P_{ih} - d_{ih} - \varepsilon).$$

[25] We will assume that all serious claims (for i and h given) are audited with the same probability β_{ih}. In other words, the audit frequency is not conditional on whether the claim is filed during the suspicious or non-suspicious period. This seems to be a realistic assumption insofar as the beginning of the policy year varies across individuals, and conditioning auditing on the date of the claim in the policy year of each individual would probably entail substantial transaction costs. Be that as it may, concentrating audits on the suspicious period individual by individual would increase the efficiency of the fraud deterrence mechanism, but this would not qualitatively affect our conclusions.

[26] The formula would be almost unchanged if the first accident also occurs in the suspicious period. In such a case, the gain from collusion would be lower (v should be replaced by a lower collusive gain v') because the advantage from bonus-malus fraud would be lower. Consequently, defrauding by filing a single claim for two minor accidents in the suspicious period does not occur for the equilibrium audit strategy.

The policyholder is willling to defraud by making a side-payment G to the car repairer if $Eu_{ih}^F \geq Eu_{ih}^N$, that is if $\beta_{ih} \leq \Psi_h(P_{ih}, d_{ih}, G)$, where

$$
\begin{aligned}
\Psi_h(P_{ih}, d_{ih}, G) \quad = \quad & \frac{q_m \mu \widehat{\pi} u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G)}{q_m \mu \widehat{\pi}[u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G) - u_h(w - P_{ih} - 2\ell - 2\varepsilon - G - B)]} \\
& + \frac{(1 - q_m \mu \widehat{\pi})[\widehat{\pi} u_h(w - P_{ih} - \ell - d_{ih} - 2\varepsilon) + (1 - \widehat{\pi}) u_h(w - P_{ih} - \ell - \varepsilon)]}{q_m \mu \widehat{\pi}[u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G) - u_h(w - P_{ih} - 2\ell - 2\varepsilon - G - B)]} \\
& - \frac{\widehat{\pi} u_h(w - P_{ih} - 2d_{ih} - 2\varepsilon) + (1 - \widehat{\pi}) u_h(w - P_{ih} - d_{ih} - \varepsilon)}{q_m \mu \widehat{\pi}[u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G) - u_h(w - P_{ih} - 2\ell - 2\varepsilon - G - B)]}.
\end{aligned}
$$

We observe that $\Psi_h(P_{ih}, d_{ih}, G) < 0$ if $d_{ih} = v = 0$, which reflects the obvious fact that no audit is required to dissuade fraud if the defrauders have nothing to earn by postponing their claims. If d_{ih} and/or v are large enough for auditing to be necessary, then we have $\Psi_h(P_{ih}, d_{ih}, G) \in (0, 1)$ and $\partial \Psi_h / \partial G < 0$. We focus on this case in what follows. The repairer agrees to collude if his expected gain from collusion is positive, that is, if

$$G - \beta_{ih} B' \geq 0.$$

The optimal side-payment offer from the policyholder to the car repairer is thus $G = \beta_{ih} B'$. The policyholder is indifferent between defrauding (through an optimal hidden agreement with the car repairer) and not defrauding if $\beta_{ih} = \Psi_h(P_{ih}, d_{ih}, \beta_{ih} B')$. This equation has a single solution $\beta_{ih} = \beta_{ih}^*(P_{ih}, d_{ih}) \in (0, 1)$ with $\beta_{ih} > \Psi_h(P_{ih}, d_{ih}, \beta_{ih})$ iff $\beta_{ih} > \beta_{ih}^*(P_{ih}, d_{ih})$. We thus have $\alpha_{ih} = 1$ - respect. $\alpha_{ih} \in (0, 1), \alpha_{ih} = 0$ - if $\beta_{ih} < \beta_{ih}^*$ - respect. $\beta_{ih} = \beta_{ih}^*, \beta_{ih} > \beta_{ih}^*$. Hence β_{ih}^* is the audit probability (for serious claims) above which type h individuals and repairers are deterred from colluding, when insurance has been purchased through distribution channel i.

3.4 Equilibrium fraud and audit

Let L_1 and L_2 be the expected repair costs, conditionally upon the occurrence of one or two accidents respectively, with[27]

$$\begin{aligned} L_1 &= (q_m + 2q_s)\ell, \\ L_2 &= 2(q_m^2 + 2q_s^2 + 3q_m q_s)\ell. \end{aligned}$$

The expected cost of claims may be written as

$$C_{ih} = \overline{L} - (\pi_1 + 2\pi_2)d_{ih} + FC_{ih} + AC_{ih}, \tag{2}$$

where $\overline{L} = \pi_1 L_1 + \pi_2 L_2$ is the expected repair cost, FC_{ih} is the expected cost of fraudulent claims, and AC_{ih} is the expected audit cost. Thus $\overline{L} - (\pi_1 + 2\pi_2)d_{ih}$ is the share of the expected repair cost borne by the insurer, and $FC_{ih} + AC_{ih}$ is the total cost of fraud. Let us express FC_{ih} and AC_{ih} as functions of fraud and audit strategies. We have

$$\begin{aligned} FC_{ih} &= \delta q_m \alpha_{ih}(\pi_1 + \pi_2)(1 - \mu) \\ &\quad \times \{q_m \mu \widehat{\pi}[(1 - \beta_{ih})(d_{ih} + v) - 2\beta_{ih}(\ell - d_{ih})] - (1 - q_m \mu \widehat{\pi})(\ell - d_{ih})\}. \end{aligned} \tag{3}$$

A policyholder who intends to renew his contract may try to defraud if his first accident is minor and if it is in the non-suspicious period, which occurs with probability $q_m(\pi_1 + \pi_2)(1 - \mu)$. He then postpones his claim with probability α_{ih}, and he will actually have the opportunity to defraud with probability $q_m \mu \widehat{\pi}$. In that case, fraud will be detected with probability β_{ih}, and no insurance indemnity will be paid for the two minor claims. With probability $1 - \beta_{ih}$, fraud is not detected and the additional cost to the insurer is $d_{ih} + v$. If the policyholder does not have the opportunity to defraud (which occurs with probability $1 - q_m \mu \widehat{\pi}$), he just loses the indemnity for the first claim $\ell - d_{ih}$.

Furthermore, we have $AC_{ih} = N_{ih} c_i$, where N_{ih} is the number of audits per type h policyholder for distribution channel i. Audits are concentrated on the first claims that

[27] If one single accident occurs, it is minor with probability q_m and serious with probability q_s, with costs ℓ and 2ℓ, respectively . In the case of two accidents, both of them are minor with probability q_m^2 and cost 2ℓ, or both are severe with probability q_s^2 and cost 4ℓ, or one is minor and the other one is serious with probability $2q_m q_s$ and cost 3ℓ.

correspond to serious accidents. Policyholders have at least one accident, the first one being serious, with probability $q_s(\pi_1 + \pi_2)$. In addition, opportunistic policyholders who intend to renew their contract file a fraudulent claim with probability $q_m^2 \alpha_{ih} \pi_2 \mu(1-\mu)$.[28] Serious accident claims are audited with probability β_{ih}. Thus, we have

$$AC_{ih} = N_{ih} c_i = \beta_{ih} c_i [q_s(\pi_1 + \pi_2) + \delta q_m^2 \alpha_{ih} \pi_2 \mu(1-\mu)]. \tag{4}$$

The audit probabilitiy β_{ih} is chosen in $[0,1]$ by the insurer to minimize the expected cost of claims C_{ih}. We thus have $\beta_{ih} = 1$ - respect. $\beta_{ih} \in (0,1), \beta_{ih} = 0$ - if $\alpha_{ih} < \alpha^*_{ih}$ - respect. $\alpha_{ih} = \alpha^*_{ih}, \alpha_{ih} > \alpha^*_{ih}$- where $\alpha^*_{ih} = \alpha^*(d_{ih}, c_i)$, with

$$\alpha^*(d,c) \equiv \frac{q_s c(\pi_1 + \pi_2)}{\delta \pi_2 q_m^2 \mu(1-\mu)(2\ell - d + v - c)}. \tag{5}$$

α^*_{ih} is the threshold fraud rate such that the insurer is incentivized to audit claims if and only if $\alpha_{ih} \geq \alpha^*_{ih}$. We have $\alpha^*_{ih} \in (0,1)$ if c_i is not too large, and we focus attention on this case in what follows.

At equilibrium, the decisions of the policyholder-repairer coalition and of the insurer should be mutual best responses. The equilibrium is in mixed strategies: insurers audit claims with a probability that makes the potential defrauder (here the policyholder-repairer coalition) indifferent between defrauding and not defrauding, and symmetrically, the fraud rate makes insurers indifferent between auditing and not auditing. This is stated in Proposition 1.

Proposition 1 *When insurers offer contract $(P_{i1}, d_{i1}), (P_{i2}, d_{i2})$ through $i \in \{D, A\}$, the equilibrium fraud rates and the equilibrium audit strategies are $\alpha_{ih} = \alpha^*(d_{ih}, c_i)$ and $\beta_{ih} = \beta^*_{ih}(P_{ih}, d_{ih})$, respectively.*

Corollary 1 *For any distribution channel $i \in \{A, D\}$, we have $\alpha_{i1} > \alpha_{i2}$ iff $d_{i1} > d_{i2}$, i.e., the larger the deductible, the larger the fraud rate.*

[28] Indeed, the policyholder has two minor accidents, the first one in the non-suspicious period and the second one in the suspicious period, with probability $q_m^2 \pi_2 \mu(1-\mu)$. He does not file a claim immediately after the first accident with probability α_{ih}.

Corollary 1 is a direct consequence of Proposition 1 because $\alpha^*(d,c)$ is increasing in d. The larger the deductible, the smaller the insurer's incentives to audit the claim, and thus the larger the minimal fraud rate that incentivizes the insurer to perform audits. In particular, everything else given (and in particular for a given distribution channel), the model predicts a larger fraud rate for deductible contracts than for full coverage contracts.

When $\alpha_{ih} = \alpha^*(d_{ih}, c_i)$, the expected cost of an insurance policy purchased by type h individuals through channel i is

$$C_{ih} = \overline{L} - (\pi_1 + 2\pi_2)d_{ih} + k_0(d_{ih} + k_1)\alpha^*(d_{ih}, c_i),$$

where $k_0 = q_m(\pi_1 + \pi_2)(1-\mu) \in (0,1)$ and $k_1 = q_m\mu\widehat{\pi}v + \ell(1 - q_m\mu\widehat{\pi})$. Insurers price their contracts with the loading factor $\sigma > 0$. Thus, we have

$$\begin{aligned} P_{ih} &= (1+\sigma)C_{ih} \\ &= (1+\sigma)[\overline{L} - (\pi_1 + 2\pi_2)d_{ih} + k_0(d_{ih} + k_1)\alpha^*(d_{ih}, c_i)], \end{aligned}$$

which may be written more compactly as

$$P_{ih} = \Phi(d_{ih}, \alpha^*(d_{i1h}, c_i)),$$

where

$$\Phi(d,\alpha) \equiv (1+\sigma)[\overline{L} - (\pi_1 + 2\pi_2)d + k_0(d + k_1)\alpha].$$

The equilibrium contract (P_{ih}, d_{ih}) maximizes $\overline{u}_h(P,d)$ subject to $P = \Phi(d, \alpha^*(d, c_i))$, and the equilibrium fraud rates are $\alpha_{ih} = \alpha^*(d_{ih}, c_i)$ for $h \in \{1,2\}$,$i \in \{A, D\}$.

Proposition 2 *The optimal insurance contracts are such that $d_{i1} \geq d_{i2} \geq 0$, with $d_{i1} > d_{i2}$ if $d_{i2} > 0$ for $i = A$ or D.*

The extent of coverage is the result of a trade-off between the incentives to audit claims and the transaction costs, materialized by the fact that the fraud rate $\alpha^*(d,c)$ is increasing in d and by the loading factor σ, respectively. In the absence of transaction costs, overcoverage would be optimal.[29] We have excluded overcoverage so that full coverage would be optimal if there were no transaction costs. However, transaction costs reduce the optimal insurance coverage. Type 1 individuals are less risk averse than type 2 individuals, and thus Proposition 2 states that their deductible is higher, as in the usual comparative statics of deductible contracts (see Schlesinger (2013)). The trade-off between increasing audit incentives and reducing transaction costs may tip in favor of positive deductibles for type 1 and full coverage for type 2, and in that case deductible and no-deductible contracts are simultaneously offered at equilibrium.[30]

Proposition 3 *At equilibrium, we have $\alpha_{D1} > \alpha_{A1}, \alpha_{D2} > \alpha_{A2}$, that is, for both types of individuals the fraud rate is larger among insurance policies purchased through D than through A.*

The intuition of Proposition 3 is the following. Insurers need additional incentives to audit claims when insurance policies have been purchased through D than through A, because establishing the truth is more costly in the first case than in the second (i.e., $c_D > c_A$). These additional incentives emerge when the fraud rate is higher, which corresponds to the fact that $\alpha^*(d,c)$ is increasing with c, hence at equilibrium there is a higher fraud rate for D than for A. The proof of Proposition 3 shows that this basic intuition remains valid if we take into account the fact that optimal deductibles may differ between both cases (i.e., we may have $d_{Dh} \neq d_{Ah}$), which also affect incentives.

There is a threshold $x_h^* \in [0,1]$ such that type h individuals located at $x \in [0,1]$ choose $i = D$ if $x < x_h^*$, and they choose $i = A$ if $x > x_h^*$. We have $P_{ih} = \Phi(d_{ih}, \alpha_{ih})$ for $i \in \{D, A\}$. Hence

$$\overline{u}_h(\Phi(d_{Dh}, \alpha_{Dh}), d_{Dh}) - tx_h^* = \overline{u}_1(\Phi(d_{Ah}, \alpha_{Ah}), d_{Ah}) - t(1 - x_h^*),$$

and thus the market share of D and A are characterized by the threshold

$$x_h^* = \frac{1}{2} + \frac{\overline{u}_h(\Phi(d_{Dh}, \alpha_{Dh}), d_{Dh}) - \overline{u}_h(\Phi(d_{Ah}, \alpha_{Ah}), d_{Ah})}{2t},$$

[29] See Boyer (2004).

[30] See the illustrative example with mean-variance preferences after the proof of Proposition 2 in Appendix 1.

for $h = 1, 2$. Let us consider the case $d_{A1} > 0, d_{D1} > 0, d_{A2} = d_{D2} = 0$, i.e., type 1 individuals chooose deductible contracts and type 2 individuals choose full coverage contracts, because the former type is less risk averse than the latter. We have $\overline{u}_1(\Phi(d_{D1}, \alpha_{D1}), d_{D1}) < \overline{u}_1(\Phi(d_{A1}, \alpha_{A1}), d_{A1})$ because $c_D > c_A$, which gives $x_1^* < 1/2$. Suppose that v is not large enough to induce fraud by type 2 individuals. In this case, we would have $\alpha_{D2} = \alpha_{A2} = 0$, and thus $x_2^* = 1/2$. The proportion of full coverage contracts among the contracts sold through D and A are respectively

$$\begin{aligned} \theta_D &= \frac{\lambda_2 x_2^*}{\lambda_1 x_1^* + \lambda_2 x_2^*} = \frac{\lambda_2}{2\lambda_1 x_1^* + \lambda_2}, \\ \theta_A &= \frac{\lambda_2(1 - x_2^*)}{\lambda_1(1 - x_1^*) + \lambda_2(1 - x_2^*)} = \frac{\lambda_2}{2\lambda_1(1 - x_1^*) + \lambda_2}, \end{aligned}$$

and $x_1^* < 1/2$ gives $\theta_D > \theta_A$. We thus observe that fraud by type 1 policyholders causes a distortion between distribution channels.

Proposition 4 *If $d_{i1} > 0$ and $d_{i2} = 0$ for $i = A, D$ and if v is not large enough to induce fraud by type 2 individals, then the proportion of full coverage contracts is larger among insurance policies purchased through D than through A.*

4 The data

Our data comes from the largest insurance company in Taiwan, with an automobile insurance market share of over 20%. Data is recorded at the individual level and provides detailed information about the policyholders, their insurance contracts and the claims they have filed. Available variables are listed in Table 1. Data has been collected over the 2010-2012 period, but our analysis will be restricted to 2010, so that we know whether policyholders subsequently renewed their contracts for less or more than one year. We target the owners of private usage small sedans and small trucks with type A, B or C insurance contracts for automobile physical damages. There are 109,461 policyholders, and 10.33% of them filed at least one claim in the year 2010, which corresponds to 11,248 observations. This subset defines our "research sample" (i.e., the sub-sample of policyholders with claims).

(Insert Tables 1, 2-1 and 2-2 here)

The mean values of the variables in the two samples are displayed in Table 2-1, with some significant differences. In particular, the research sample includes a larger proportion of female owners, medium-sized and new vehicles, with a larger share for one brand. More importantly, the research sample includes a larger fraction of policyholders who belong to the $SG2$ group and who have purchased insurance through the DOA channel than the whole sample (5.68% vs 2.85%, and 79.98% vs 50.78%, respectively). The share of the RG group also increases from 19.8% in the whole sample to 39.42% in the research sample. Table 2-2 separates the research sample into two subgroups, according to the insurance distribution channels (DOA and non-DOA), with significant differences in terms of gender, usage, and vehicle size. There is also a higher proportion of new vehicles for the DOA channel, which reflects the fact that DOAs sell both vehicles and insurance contracts. On average, the bonus-malus coefficient is significantly higher in the DOA group than in the non-DOA group, but insurance premiums do not significantly differ between the two groups.[31] Furthermore, the percentage of insured parties who belong to the SG group is significantly higher in the DOA channel than in the non-DOA channel, for $SG1$ (70.29% and 51.78%, respect.) as well as $SG2$ (6.35% and 3.01%, respect.) The percentage of claims filed in the suspicious period (defined as the last month of the policy year) is 54.66% in the non-DOA channel, and it rises to 67.19% in the DOA channel. We may also observe that the share of the RG group is significantly lower in the DOA channel (34.28% vs 59.92%). Finally, the percentage of no-deductible contracts sold through the DOA channel is larger than that in the non-DOA channel (93.63% vs 91.34%).

[31] It is indeed well known in Taiwan that individuals with less favorable claim records (and thus with a higher bonus-malus coefficient) tend to purchase insurance through a DOA, and that some DOAs may unduly protect their customers from a strict enforcement of the bonus-malus rule.In Taiwan, a driver's bonus-malus coefficient is public information and thus, in principle, an insurance company should be in the position to adjust the premium in each policy year even if policyholders switch from one insurance company to another. However, in practice, for the sake of keeping customers or winning new customers, insurance companies sometimes do not strictly enforce the bonus-malus rule. This is particularly the case when DOAs make use of their bargaining power to act on behalf of their customers so as to protect them from an increase in premium.

5 Testing hypotheses

Our first hypothesis is related to the fact that the perspective of contract renewal and the choice of a deductible contract are factors that stimulate fraud. Since we focus on the fraudulent behavior that consists of manipulating the claim date by moving it to the end of the policy year (possibly by filing one claim for two events), we define the fraud rate as the percentage of claims in the suspicious period.[32]

Hypothesis 1: *The fraud rate is higher in the suspicious group than in the non-suspicious group, and this is particularly the case for individuals covered by deductible contracts.*

According to Hypothesis 1, the policyholders from suspicious groups $SG1$ and $SG2$ have a larger propensity to file a claim during the suspicious period than the other policyholders (the control group). Testing this hypothesis amounts to identifying whether there is a conditional dependence between belonging to the suspicious group SG (or to one of its subgroups $SG1$ and $SG2$), and filing a claim within the suspicious period (evaluated by the dummy SC). To do so, we use a two-stage method, similar to the approach that has been followed by Dionne et al. (1997, 2001) in a setting with asymmetric information about risk types.[33]

For notational simplicity, $SG, SG1, SG2$ also denote dummies for belonging to suspicious groups $SG, SG1$ and $SG2$, respectively. Testing the conditional dependence between $SG1$ and SC and between $SG2$ and SC leads us to instrument two decisions at the first stage. One is the decision to renew the contract or not ($SG = 0$ or 1),[34] and the other refers to the contract choice ($deduct = 0$ or 1). These two decisions lead to the two endogenous variables:

$$\begin{aligned} SG1 &= \begin{cases} 1 \text{ if } SG = 1 \text{ and } deduct = 0, \\ \quad\quad 0 \text{ otherwise.} \end{cases}, \\ SG2 &= \begin{cases} 1 \text{ if } SG = 1 \text{ and } deduct = 1, \\ \quad\quad 0 \text{ otherwise.} \end{cases} \end{aligned}$$

[32] Of course, this does not mean that all the claims filed in the suspicious period are fraudulent.

[33] They aim at appraising whether the correlation between claims and coverage reflects individuals' unobservable characteristics, which are not used by insurers in underwriting and pricing decisions. In order to avoid a spurius correlation caused by misspecification, they add the conditional expectation of one decision variable (such as filing a claim) when regressing on the other one (such as choosing the insurance coverage). To avoid endogeneity problems, Dionne et al. (2009) and Dionne et al. (2014) estimate this conditional expectation through an instrumental variable approach.

[34] We define the suspicious group (SG) as the set of individuals who renew their contract at the end of the policy year.

SG and *deduct* are estimated at the first stage by bivariate Probit regressions, with an instrumental variable approach. This requires finding out some factors that are related to the decisions of renewing the contract and choosing full coverage, in addition to the underwriting and pricing variables, and that are unrelated to the decision of filing a suspicious claim.

Firstly, the income of an individual may affect his decisions about the contract and about his mobility between insurers, but there is no obvious reason for which income should be related to the decision of filing a claim during the last policy month. The income level is thus a first candidate instrumental variable. Unfortunately, our database does not provide information about the income level of each policyholder. As an approximation, we will use a variable that corresponds to the average income level in the zip code area of the policyholder. We will separate the wealthiest areas from the poorest ones through a dummy variable $income_i$, indicating that insured i lives in an area where the average income is in the top 25% tranche over the whole country.

Secondly, the insurance distribution channel may affect the contract choice as well as the renewal decision. In particular, DOAs own large market shares in Taiwan, they have tight relationships with their customers, and they are in a favorable position to push customers to renew their contracts and to choose more expensive no-deductible contracts. This potential influence of DOAs will be taken into account through the dummy variable $dealer_i$, indicating that individual i lives in a zip code area where the density of DOAs is in the top 25% tranche. There is no obvious reason for which the propensity to file a claim during the suspicious period would be affected by the local density of DOAs, which leads us to treat $dealer_i$ as another candidate instrumental variable.[35]

Accordingly, at stage 1 Bivariate Probit regressions are written as

$$\begin{aligned}&\Pr(SG_i = 1 | income_i, dealer_i, X_i)\\&= \Phi(\beta_{inc} income_i + \beta_d dealer_i + \alpha X_i + \varepsilon_{SGi}),\end{aligned} \tag{6}$$

[35] Other thresholds (10%, 20%, 30% 40%, and 50%) have been tested, and it turned out that the 25% criterion yields the best instrumental variable.

$$\Pr(deduct_i = 1 | income_i, dealer_i, X_i)$$
$$= \Phi(\beta_{inc} income_i + \beta_d dealer_i + \alpha X_i + \varepsilon_{dedti}), \tag{7}$$
$$cov(\varepsilon_{SGi}, \varepsilon_{dedti}) = \rho, \tag{8}$$

where X_i is the column vector of underwriting and pricing variables for policyholder i, including: gender and age of the policyholder, usage, brand, size and age of the insured vehicle. This is the first group of explanatory variables in Table 1.

At stage 2, we estimate the probability that policyholders file their first claim during the suspicious period. We explore the conditional dependence between SC and $SG1$ and between SC and $SG2$, by considering $\Pr(SG1_i) \equiv \Pr(SG_i = 1, deduct_i = 0)$ and $\Pr(SG2_i) \equiv \Pr(SG_i = 1, deduct_i = 1)$ as explanatory variables in a second stage Probit regression, which is written as

$$\Pr(SC_i = 1 | \Pr(SG1_i), \Pr(SG2_i), RG_i, X_i)$$
$$= \Phi(\beta_{instr1} \Pr(SG1_i) + \beta_{instr2} \Pr(SG2_i) + \beta_r RG_i + \beta X_i), \tag{9}$$

where $SC_i = 1$ when policyholder i files his first claim during the suspicious period and $SC_i = 0$ otherwise. To control for the possibility that last policy-month claims may result from a premium recouping behavior, we also use the control variable RG_i (with $RG_i = 1$ when the contract is of type A or B and has not been subsequently renewed for more than one year, and $RG_i = 0$ otherwise). Here, also, X_i is the column vector that contains first group explanatory variables of Table 1.

Dionne et al. (2001) argue that the explanatory variables of stage 2 regression should also include dummies for the variables instrumented at stage 1. We refer to this method as the DGV approach. It leads to the following stage 2 regression:

$$\Pr(SC_i = 1 | \Pr(SG1_i), \Pr(SG2_i), SG1_i, SG2_i, RG_i, X_i)$$
$$= \Phi(\beta_{instr1} \Pr(SG1_i) + \beta_{instr2} \Pr(SG2_i) + \beta_{s1} SG1_i + \beta_{s2} SG2_i + \beta_r RG_i + \beta X_i). \tag{10}$$

In the 2SLS approach (regression (9)), the conditional dependence between $SG1$ and SC as well as between $SG2$ and SC is evaluated through the estimated coefficients of $\Pr(SG1_i)$ and $\Pr(SG2_i)$, i.e., by β_{instr1} and β_{instr2}, respectively. In the DGV approach (regression (10)), the conditional dependence is evaluated by the overall sum of the estimated coefficients of $\Pr(SG1_i)$ and $SG1_i$ and the sum of the estimated coefficients of $\Pr(SG2_i)$ and $SG2_i$, i.e., by $\beta_{instr1} + \beta_{s1}$ and $\beta_{instr2} + \beta_{s2}$, respectively.[36]

(Insert Table 3 here)

The first stage bivariate Probit estimations are listed in the two first columns of Table 3, with intuitive results. The inhabitants of higher income areas have a lower probability of continuing the same contract, and a higher probability of purchasing a deductible contract. This is consistent with a decreasing absolute risk aversion assumption: in a setting where individuals may have partial information on the quality of insurance contracts, less risk averse individuals are less reluctant to move from an insurer to another one, and they also tend to choose lower coverage. Furthermore, inhabitants of high DOA density areas are more likely to continue the same contract and their probability to choose a deductible contract is lower, which is consistent with the presumption that DOAs tend to steer their customers in a direction that is in their own interest. Policyholders from the premium recouping group are less likely to continue the same contract for at least one year (which simply reflects the definition of RG), and they tend to opt for deductible contracts. We also see that the owners of larger vehicles are comparatively more likely to renew their insurance contract and to opt for a contract with a deductible.

The results of the second-stage estimation by the 2SLS approach with the Probit model are reported in the third column of Table 3. They show the conditional dependence between SC and either $SG1$ or $SG2$, with coefficients 1.5688 and 2.0479 that are significant at the 1% level. The fourth column corresponds to the second stage of the DGV approach. The estimated coefficients of $\Pr(SG1)$ and $\Pr(SG2)$ are significantly different from 0 at the 1% level,

[36] As a preliminary step, the 2SLS approach requires testing (1) whether there is a weak instrument problem by the Anderson-Rubin test, (2) whether the instrument is over-identified by Sargan's J test, and finally (3) whether the instrumental variable method is relevant by the Durbin-Wu-Hausman test. Dionne et al. (2014) state that estimating the conditional probability of the instrumented variable through LPM or through the Probit model is qualitatively consistent with the 2SLS approach. Estimating $\Pr(SG_i = 1 | income_i, dealer_i, X_i)$ and $\Pr(deduct_i = 1 | income_i, dealer_i, X_i)$ by two LPMs and performing these three tests validates our instrumental variable approach. The results of these tests are in Table 8 in the Appendix.

which confirms the existence of an endogeneity problem. The dummy variables $SG1$ and $SG2$ are also significantly different from 0 at the 5% and 1% threshold, respectively, which confirms the conditional dependency between SC and $SG1$ or $SG2$, with total coefficients $1.3591 = 1.0427 + 0.3164$ and $2.1910 = 1.7074 + 0.4836$, respectively.

Thus, the 2SLS and DGV approaches lead to similar conclusions, and they confirm our presumption of a positive conditional dependence between belonging to $SG1$ or $SG2$ and filing a first claim during the suspicious period, which supports Hypothesis 1.

Remark 1: *Table 3 also offers some interesting byproducts that are worth mentioning. Firstly, the owners of vehicles that are new or less than three years old tend to file their first claim during the suspicious period, which reflects the "car wash" phenomenon in Taiwan's insurance market. Secondly, the policyholders from the premium recouping group also tend to file their first claims in the suspicious period, which echoes the conclusions of Li et al. (2013). Thirdly, females also file their first claim during the suspicious period more frequently than males, but that does not necessarily reflect a gender effect in fraudulent behavior. It is usual in Taiwan to register cars under the name of females (e.g., a wife or mother), even when the primary driver is a male, in order to benefit from cheaper insurance premiums. Hence, instead of a gender effect, the above mentioned correlation may just reflect the fact that the policyholders who carefully manage their insurance budget may also try to obtain undue advantage from their insurance company.*

For the sake of robustness verification, we have also followed the approach of Chiappori and Salanié (2000). They use a pair of Probit regressions to explain the probability of filing a claim and the probability of choosing partial coverage, and they appraise the conditional dependence between these two variables by submitting the residuals of the two regressions to a W test. Similarly, two sets of pairwise Probit regressions have been run. The first ones are performed among the policyholders who are either in $SG1$ or in neither $SG1$ nor $SG2$, and they aim at estimating the conditional correlation between $SG1$ and SC. The second set of pairwise regressions are performed among the policyholders who are either in $SG2$ or in neither $SG1$ nor $SG2$, and they allow us to estimate the conditional correlation between $SG2$ and SC. Two W statistics, calculated with the residuals of the two regressions in each set, are significantly different from 0 at the 1% threshold. We have also calculated the correlation coefficient of these residuals for each set, and find that both are positive and significantly different from 0 at the 1% level.[37] Hence, the empirical results from this robustness test also support to our Hypothesis 1.

If defrauders postpone their claims to the suspicious period and if they may cumulate losses in a unique claim, then the suspicious period should be characterized by high values of first-claim cost ratios. This is expressed in Hypothesis 2.

Hypothesis 2: *The first-claim cost ratio is larger in the suspicious period than during the rest of the policy year, particularly for the suspicious group.*

Hypothesis 2 is tested through the following regression:

$$clmamt_i = \alpha_c SC_i + \alpha_f first_i + \alpha_{fs} first * SC_i + \alpha X_i, \tag{11}$$

which is performed among the claims filed by members of the SG group, where $clmamt_i$ is the value (in US dollars) of the claims filed by policyholder i. In regression (11), we use two additional variables ($first_i$ and $first_i * SC_i$) besides SC_i and vector X_i. $first_i = 1$ when this is the first claim filed by policyholder i during the policy year, otherwise $first_i = 0$ and $first * SC_i$ is an interaction variable. We perform the above test separately for $SG1$ and $SG2$. In our sample, this corresponds to 9,741 claims filed by 7,489 policyholders from the $SG1$ group, and 763 claims filed by 639 policyholders from the $SG2$ group. The estimated coefficient of the interaction term $\widehat{\alpha}_{fs}$ is the key to test. We obtain $\widehat{\alpha}_{fs} = 149.37$ with $p-$value 0.1014 for $SG1$, and $\widehat{\alpha}_{fs} = 249.33$ with $p-$value 0.0658 for $SG2$. To some extent, these results confirm the validity of Hypothesis 2, with a lower significance level for $SG1$ than for $SG2$.[38] To complete this verification, we run the regression that explains the value of the claims over the whole sample (not only the SG group) by including dummies $SG1_i, SG2_i, SC_i, first_i$, and their double and triple interaction terms in the explanatory variables. Furthermore, in order to be able to identify fraud (as defined above, that is claims manipulation) and the premium recouping behavior, we also include RG_i, and the double and

[37] Computing the W statistic with the residuals of the regressions for $SG1$ and SC yields $W = 201.76$, which is significantly different from 0 at the 1% level. The correlation coefficient between the residuals of these regressions is $\rho = 0.003611$, and it is also significantly different from 0 at the 1% level. Likewise, using the residuals from the regressions for $SG2$ and SC gives $W = 257.99$ and $\rho = 0.03221$, and these statistics are significantly different from 0 at the 1% level. The full regression results are not reported here because of space constraints, but they are available from the authors upon request.

[38] This is consistent with the fact that the policyholders with deductible contracts (i.e., the $SG2$ subgroup) have a greater incentive to file a unique claim for two events than the policyholders with no-deductible contracts (the $SG1$ subgroup).

triple interaction variables $RG_i * SC_i$, and $RG_i * SC_i * first_i$ among explanatory variables.

$$
\begin{aligned}
clmamt_i \quad = \quad & \alpha_{s1}SG1_i + \alpha_{s2}SG2_i + \alpha_{RG}RG_i + \alpha_c SC_i + \alpha_f first_i \\
& +\alpha_{cf}SC_i * first_i + \alpha_{sf1}SG1_i * first_i + \alpha_{sf2}SG2_i * first_i \\
& +\alpha_{Rf}RG_i * first_i + \alpha_{sc1}SG1_i * SC_i + \alpha_{sc2}SG2_i * SC_i + \alpha_{Rc}RG_i * SC_i \\
& +\alpha_{scf1}SG1_i * SC_i * first_i + \alpha_{scf2}SG2_i * SC_i * first_i \\
& +\alpha_{Rcf}RG_i * SC_i * first_i + \alpha X_i. \qquad (12)
\end{aligned}
$$

Performing this regression among the 14,797 claims filed by the members of the research sample gives $\widehat{\alpha}_{scf1} = 369.97$ with $p-$value <0.0154, $\widehat{\alpha}_{scf2} = 532.57$ with $p-$value <0.0001, and $\widehat{\alpha}_{Rcf} = -10.11$ with $p-$value <0.0581.[39] The inequalities $\widehat{\alpha}_{scf2} > \widehat{\alpha}_{scf1} > 0$ once again validate Hypothesis 2. Symmetrically, $\widehat{\alpha}_{Rcf} < 0$ confirms that members of the RG group tend to file small claims at the end of the policy year, when they have not filed any claim during the previous months.

Remark 2: *It is worth observing that these conclusions derived from regression (12) should not be attributed to (ex ante) moral hazard or adverse selection. Ex ante moral hazard explains why a more comprehensive insurance coverage may make a driver less cautious. This incentive effect is even stronger for policyholders who had no accidents before the suspicious period, because the bonus-malus system forgives the first accident. Hence, under the moral hazard hypothesis, the policyholders from the $SG1$ group (i.e., those with a no-deductible contract) should be less cautious than those from $SG2$ (the policyholders with a deductible contract), and according to the moral hazard interpretation, they should have more severe first accidents in the last policy month. Regression (12) predicts exactly the contrary.*

Let us investigate now how adverse selection may affect our results. Firstly, in a setting with hidden information about risk types, past and future claim experiences may be linked, but man-made claim manipulation should reduce the predictive power of this link. To check if this is actually the case, we use the 2010 data to run two Probit regressions that estimate the probability of filing a claim either in any month of 2011 or in the suspicious period of 2011, respectively. The regressions were run separately for the suspicious and non-suspicious groups.[40] *Observing the policyholders' 2011 claim records allows us to calculate the prediction*

[39] The full estimated results of regressions (11) and (12) are available from the authors upon request.

[40] In other words, these Probit regressions regress clm_i and SC_i, respectively, on the explanatory variables

error for the claims filed in all of 2011 and for the claims filed in the suspicious period of 2011. In a second stage, we use a t-test to evaluate whether this prediction error is smaller for the claims filed over the whole year than for those filed in the suspicious period.[41] *Panel A of Table 4 confirms that this is the case, at the same time for both the suspicious and non-suspicious groups. Furthermore, the difference of the prediction error is significantly different and larger in absolute value in the suspicious groups, especially in* $SG2$*, than in the non-suspicious group. This confirms the manipulation of claims, beyond any possible hidden information about policyholders' risk types.*

Secondly, we know that adverse selection may lead to a positive correlation between the contract coverage and the probability of filing claims, but it does not induce any particular timing for claims such as the one on which we are focusing. Panel B of Table 4 provides the hazard rate in the suspicious groups $SG1$ *and* $SG2$*, and in the non-suspicious group. In* $SG1$ *and* $SG2$*, the hazard rates are significantly higher in the last policy month than in the other months, and these last month hazard rates are significantly higher than in the non-suspicious group, which confirms that claim manipulation does occur. The fact that the last month hazard rate is even larger for* $SG2$ *than for* $SG1$ *confirms that our observations cannot be attributed to adverse selection.*

(Insert Table 4 here)

Remark 3: *We may also be worried by the fact that* $SG2$ *includes two types of deductible contracts, with more extensive exclusions for type B than for type A. To control for any disturbances that may be linked to this difference in the scope of coverage, we perform a robustness test, in which we limit our sample to type-B contracts.*[42] *The empirical results are listed in Table 5. Basically, the results are consistent with those of Table 3, which confirms the robustness of our results.*

(Insert Table 5 here)

Beyond the mere fact that fraud does exist, estimating its cost is also important. To

included in the vector of observable variables X_i.

[41] The prediction error is the absolute value of the difference between the estimated probability of filing a claim and the dummy equal to 1 if the individual has filed a claim in 2011 and 0 otherwise. We calculate the difference between the prediction errors over the whole 2011 year and over the suspicious period, and we test whether this difference is negative.

[42] In other words, in this test, the suspicious group includes the policyholders (from the $SG1$ group) with a no-deductible type B contract that has been renewed at the end of the policy year, and the policyholders (from the $SG2$ group) with a deductible type B contract that has been renewed at the end of the policy year, while the control group contains the other policyholders with a type B contract that has not been renewed.

do this, we refer to the empirical results from the DGV model. The estimated coefficients of $\Pr(SG1)$ and $SG1$ are 1.0427 and 0.3164 (see the fourth column in Table 3), and their marginal effects are 0.3806 and 0.1155, respectively. This implies that, overall, the probability of filing a claim in the suspicious period increases by 49.61% when comparing a policyholder from the $SG1$ group to those in the non-suspicious group. The average cost of non-detected fraudulent claims is NT\$5,027 if we presume that fraud is committed by filing a unique claim for two events, postponed to the last month of the policy year to avoid the penalty from the bonus-malus rule.[43] This implies that the difference in annual fraud cost between members of the $SG1$ group and policyholders from the non-suspicious group is about NT\$2,494. Likewise, the estimated coefficients of $\Pr(SG2)$ and $SG2$ are 1.7074 and 0.4836, with marginal effects 0.6232 and 0.1765, respectively, which implies that the probability of filing a claim in the suspicious period increases by 79.97% when we compare members of the $SG2$ group to policyholders from the non-suspicious group. The average cost of a fraudulent claim is NT\$10,027, once again with the assumption that defrauders file a unique claim for two events and postpone their claim to the last month of their policy year.[44] This implies that the policyholders from the $SG2$ group entail an expected cost of fraud that is about NT\$8,019 higher than for the insured from the non-suspicious group. Since there are 7,489 and 639 policyholders in $SG1$ and $SG2$, respectively, we may deduce that the expected cost of fraud is about NT\$23,801,707, which represents 8.74% of the total premiums paid by the policyholders from our sample (NT\$2.724 billion). These are of course very crude estimates, but they give an idea of the cost of fraud through claims manipulation in Taiwan.

Our third hypothesis is inspired by Proposition 3; it relates the fraud rate to the insurance distribution channel.

Hypothesis 3: *The fraud rate in the suspicious group is comparatively even larger when insurance has been purchased through the DOA channel than through other distribution channels.*

[43] The average insurance premium in our research sample is NT\$ 25,136. We may roughly estimate that the defrauders who file a unique claim for two events and postpone their claim to the last month of their policy year avoid about 20% of this amount: 10% because of the decrease in the number of claims, and 10% because the increase in premium will be postponed for one year.

[44] This cost includes the avoided deductible and the avoided bonus-malus penalty. The deductibles of first and second claims are NT\$3,000 and NT\$5,000 respectively, hence there is a NT\$5,000 fraud cost when policyholders file a unique claim to cover two accidents. Adding the NT\$5,027 avoided penalty due to the increase in premium to the deductible of the second claim yields a total fraud cost of NT\$10,027.

Testing the validity of Hypothesis 3 will follow the same approach as for Hypothesis 1. Dummy D_i indicates that policyholder i has purchased insurance through the DOA channel, and now three endogenous variables, $SG_i, deduct_i$ and D_i, must be instrumented in the 2SLS approach. As previously, SG_i and $deduct_i$ are instrumented by $income_i$ and $dealer_i$ through bivariate Probit regressions, leading to $SG1_i = \Pr(SG_i = 1, deduct_i = 1)$ and $SG2_i = \Pr(SG_i = 1, deduct_i = 0)$. Furthermore, $dealer_i$ and $income_i$ are also candidate instruments for D_i, because a large DOA density may be an encouragement to purchase insurance from a DOA, and because people with high income may have larger search costs, which may lead them to purchase insurance from a DOA. This is particularly the case when individuals purchase a new car, hence a third instrumental variable new_i, which indicates that the insured vehicle is less than three years old. Thus, D_i is instrumented by:

$$\begin{aligned}&\Pr(D_i = 1|income_i, dealer_i, new_i, X_{2i})\\&= \Phi(\beta_{icm} income_i + \beta_d dealer_i + \beta_{new} new_i + \alpha X_{2i}).\end{aligned} \tag{13}$$

Stage 2 of the 2SLS approach is now written as:

$$\begin{aligned}&\Pr(SC_i = 1|\Pr(SG1_i), \Pr(SG2_i), \Pr(D_i), RG_i, \Pr(D_i) * \Pr(SG1_i), \Pr(D_i) * \Pr(SG2_i), \Pr(D_i) * RG_i, X_{2i})\\&= \Phi(\beta_{instr1} \Pr(SG1_i) + \beta_{instr2} \Pr(SG2_i) + \beta_D \Pr(D_i) + \beta_r RG_i\\&+\beta_{Dinstr1} \Pr(D_i) * \Pr(SG1_i) + \beta_{Dinstr2} \Pr(D_i) * \Pr(SG2_i) + \beta_{Dr} \Pr(D_i) * RG_i + \beta X_{2i}),\end{aligned} \tag{14}$$

with $\Pr(SG1_i), \Pr(SG2_i)$, and $\Pr(D_i) \equiv \Pr(D_i = 1)$ being estimated at stage 1. In particular, we include interaction terms $\Pr(D_i) * \Pr(SG1_i)$ and $\Pr(D_i) * \Pr(SG2_i)$ in order to evaluate whether the conditional dependence between $SG1$ and SC and between $SG2$ and SC are comparatively higher in the DOA channel. The premium recouping effect and its interaction with the DOA channel are also taken into account through RG_i and $\Pr(D_i) * RG_i$, respectively.

At Stage 2 of the DGV approach, the explanatory variables include the dummy variables $SG1_i, SG2_i$ and the two estimated variables $\Pr(SG1_i), \Pr(SG2_i)$, with interaction terms to assess whether the conditional dependence between $SG1$ and SC and between $SG2$ and SC

is affected by the DOA channel. This is written as:

$$
\begin{aligned}
&\Pr(SC_i = 1 | \Pr(SG1_i), \Pr(SG2_i), SG1_i, SG2_i, \Pr(D_i), RG_i, \\
&\Pr(D_i) * \Pr(SG1_i), \Pr(D_i) * \Pr(SG2_i), \Pr(D_i) * SG1_i, \Pr(D_i) * SG2_i, \Pr(D_i) * RG_i, X_{2i}) \\
&= \Phi(\beta_{instr1} \Pr(SG1_i) + \beta_{instr2} \Pr(SG2_i) + \beta_{S1} SG1_i + \beta_{S2} SG2_i + \beta_D \Pr(D_i) + \beta_r RG_i \\
&+\beta_{Dinstr1} \Pr(D_i) * \Pr(SG1_i) + \beta_{Dinstr2} \Pr(D_i) * \Pr(SG2_i) + \beta_{DS1} \Pr(D_i) * SG1_i \\
&+\beta_{DS2} \Pr(D_i) * SG2_i + \beta_{Dr} \Pr(D_i) * RG_i + X_{2i}\beta).
\end{aligned}
$$

The results are in Table 6.[45] The first column lists the estimated coefficients of the first stage regression for $\Pr(D)$: they confirm that individuals living in areas with high average income and high DOA density tend to purchase insurance through the DOA channel. This is also the case for the owners of vehicles that are less than three years old.

The 2SLS and DGV Probit regressions for SC are in the second and third columns. In the 2SLS Probit model, the estimated coefficients of $\Pr(SG1)$ and $\Pr(SG2)$ are 0.6843 and 1.0644, and they are significantly different from 0 at the 10% and 5% levels, respectively. The estimated coefficients of $SG1 * \Pr(D\ )$and $SG2 * \Pr(D)$ are 1.0477 and 1.1005, and they are significantly different from 0 at the 1 % level. All in all, this confirms that there is a significant conditional dependence between belonging to the suspicious group and filing claims during the suspicious period. This conditional dependence is even stronger among the insured who have purchased insurance through the DOA channel, and these effects are stronger for $SG2$ than for $SG1$. In other words, we may conclude that the fraud phenomenon associated with the claim date manipulation does exist, and that it is more severe among those individuals with deductible contracts and who have purchased insurance through the DOA channel, which confirms the prediction from Hypothesis 3.

(Insert Table 6 here)

The third column of Table 6 corresponds to the DGV model. The most relevant results are the following. The estimated coefficients of $\Pr(SG2)$ and $SG2$ are equal to 0.8930 and 0.1930, with significance level 1% and 10%, respectively, and an overall effect of 1.0860. The

[45] Here we have also checked the robustness of our IV method by using two sets of 2SLS-LPM and by checking that the null hypothesis of irrelevant model is rejected by the Durbin-Wu-Hausman test, the null hypothesis of exogenous instrumental variable cannot be rejected by the Anderson-Rubin test, and the null hypothesis of no-over identification cannot be rejected by the J test.

estimated coefficients of $\Pr(SG1)$ and $SG1$ are equal to 0.4762 and 0.0845, respectively, but the second one is not significant. The coefficients of interaction terms $\Pr(D) * \Pr(SG1)$ and $\Pr(D) * \Pr(SG2)$ are equal to 0.7134 and 0.9773 and they are significant at the 1% level. Similar conclusions are obtained for $\Pr(D) * SG1$ and $\Pr(D) * SG2$, with significance levels of 10% and 5%, respectively. It is particularly interesting to observe that each coefficient in the DOA channel is larger than its equivalent in the non-DOA channel, which confirms the role of DOAs in the fraud process. Furthermore, whatever the distribution channel, the $SG2$ coefficients are larger than their $SG1$ equivalents, which confirms that deductible contracts exacerbate fraudulent behaviors.

Calculation shows that the marginal effect of the estimated coefficients of $\Pr(D_i) * SG1_i$ and $\Pr(D_i) * \Pr(SG1_i)$ are equal to 0.1016 and 0.2517, which implies that, in the $SG1$ group, the probability of filing a claim during the suspicious period is 35.33% larger when policyholders have purchased insurance through the DOA channel than through another channel. Thus, if the expected cost of a fraudulent claim by an $SG1$ policyholder is NT$5,027, as we have already estimated, then the expected fraudulent claim cost of such policyholders is NT$1,776 larger when insurance has been purchased through the DOA channel than through another channel. The marginal effect of the estimated coefficients of $\Pr(D_i) * SG2_i$ and $\Pr(D_i) * \Pr(SG2_i)$ are equal to 0.1214 and 0.3448, thus with a 46.62% larger probability of filing a claim in the suspicious period for a member of the $SG2$ group who has purchased insurance through the DOA channel rather than through another channel. For an expected cost of fraudulent claims in the $SG2$ group equal to NT$10,027, this amounts to an increase of NT$4,675 in the expected cost of fraud when an $SG2$ policyholder takes out insurance from a DOA rather than through another distribution channel.

At the end, we may calculate the increase in fraud cost for each suspicious subgroup by comparison with the non-suspicious group. For example, 6,323 policyholders in $SG1$ have taken out insurance through the DOA channel, with an expected increase in fraudulent claiming of NT$2,770, and hence a total additional cost of NT$17,514,710. Similar calculations for the other cases yield the following results:[46]

[46] In our research sample, 571 individuals from the SG2 group have taken out insurance from DOAs. There are 1,166 and 68 members in the Non-DOA group, for SG1 and SG2 respectively.

Increase in the cost of fraud	DOA	Non-DOA
$SG1$	$6,323 \times 2,770 = \$17,514,710$	$1,166 \times 994 = \$1,159,004$
$SG2$	$571 \times 8,517 = \$4,863,207$	$68 \times 3,842 = \$261,256$
$SG1 + SG2$	$\$22,377,917$	$\$1,420,260$

Hence the suspicious policyholders in $SG1$ and $SG2$ who have purchased insurance through the DOA channel are at the origin of an increase in the cost of fraud that can be estimated at NT $\$22,377,917$, which corresponds to about 8.22% of the premium written by this company for this line of business. The estimated increase in fraud cost is only $\$1,420,260$, that is 0.52% of the premium written.

A legitimate question that may arise is whether the higher expected cost of claims in the DOA channel comes from fraudulent behaviors, as we have argued so far, or whether it rather reflects the fact that, on average, the individuals who take out insurance from DOAs have higher risks. This issue may be clarified by estimating the claim amount using the following OLS regression:

$$claimamt_i = \alpha_0 + \alpha_D D_i + \alpha_A A_i + \alpha_B B_i + \alpha_{DA} D_i * A_i + \alpha_{DB} D_i * B_i + X_i \alpha_X + \varepsilon_i. \quad (15)$$

A_i and B_i are dummies for type A or B contracts, respectively, with type C contract as counterpart, and X_i includes the underwriting and pricing variables as in the previous regressions. The estimated results are in Table 7. Type A and B contracts are associated with claim costs that are significantly larger than for type C contracts. The estimated coefficient of D_i is negative, but it is not significantly different from 0. Likewise, the estimated coefficients of interaction terms $D_i * A_i$, and $D_i * B_i$ are not significantly different from 0. In other words, the policyholders of the DOA channel do not have higher claim costs than others, whatever their contract. Hence, the increase in claim costs is not an intrinsic characteristic of the distribution channel: it reflects the fraudulent behaviors of some policyholders (the suspicious groups) who may take advantage of the manipulation of claims, and this behavior is facilitated by DOAs.

Remark 4: *Apart from these main results, Table 6 also provides two interesting by-products that are common to the 2SLS and DGV Probit models. Firstly, the estimated* *coefficient of RG_i is positive and significantly different from 0, at least at the 10% level, which confirms the existence of the premium recouping behavior. However, the estimated coefficients of the interaction term $RG_i * \Pr(D_i)$ have negative signs that are not significant. Thus, compared to other distribution channels, DOAs do not particularly help opportunistic policyholders to recoup premiums at the end of the policy year. Their behavior, as an act of collusion, rather focuses on the manipulation of the claim date. Secondly, the estimated coefficient of $female_i$ is positive and significant. This confirms that fraudulent behaviors may be widespread among those individuals who carefully manage their budget, since the declared gender of the owner of the car may be manipulated to take advantage of a lower premium. This is consistent with our previous observation made regarding Table 3.*

Hypothesis 4: *The proportion of no-deductible contracts is larger when contracts are sold through the DOA channel.*

Finally, Hypothesis 4 reflects Proposition 4. We test this hypothesis by using the whole sample (not only the subsample of policyholders with claims). In a first step, we estimate the probability of choosing the DOA channel (i.e., $\Pr(D_i)$) by regression (13), and in a second step we test the following regression:

$$\Pr(nodedt_i = 1 | \Pr(D_i), B_i, X_{2i}) = \Phi(\beta_D \Pr(D_i) + \beta_B B_i + \beta X_{2i}), \tag{16}$$

where $nodedt_i = 1$ when policyholder i chooses a no-deductible contract, and $nodedt_i = 0$ otherwise. Contracts may also differ through different exclusions, and the additional dummy B_i is used to control for this heterogeneity. Estimation gives $\widehat{\beta}_D = 1.2499$, with a $p-$value smaller than 0.0001, which confirms the validity of Hypothesis 4.

We may also control for the unobservable heterogeneity between individuals, particularly in terms of risk type through a two-stage method. In the first stage, we test

$$\begin{aligned}
&\Pr(clm_i = 1 | income_i, dealer_i, new_i, X_{2i}) \\
&= \Phi(\beta_{icm} income_i + \beta_d dealer_i + \beta_{new} new_i + \alpha X_{2i}),
\end{aligned} \tag{17}$$

where $clm_i = 1$ if individual i has filed a claim and $clm_i = 0$ otherwise. In the second stage, we use the DGV model to control for unobservable heterogeneity. This is written as :

$$\begin{aligned}
&\Pr(nodedt_i = 1 | \Pr_i(clm_i), clm_i, \Pr(D_i), B_i, X_i) \\
&= \Phi(\beta_{ec} \Pr(clm_i) + \beta_c clm_i + \beta_D \Pr(D_i) + \beta_B B_i + \beta X_i), \qquad (18)
\end{aligned}$$

where $\Pr(clm_i) \equiv \Pr(clm_i = 1)$ and $\Pr(D_i)$ is the estimated probability of choosing the DOA channel. We obtain $\widehat{\beta}_D = 1.0111$ with a $p-$value smaller than 0.0060, which once again confirms the previous result, but at a lower significance level.

6 Conclusion

This paper has focused attention on the policyholder-service provider coalition in insurance mechanisms: how it can affect the credibility of claim auditing, how several patterns of fraud may emerge in the car insurance market, and how service providers and policyholders may draw benefit from such a coalition. The important role of car dealers in Taiwan provides an exceptional opportunity to analyze this interaction between insurer, policyholder and provider.

Indeed, the economic analysis of insurance fraud is usually based on a very abstract picture of claims fraud (filing a fraudulent claim although no accident has occurred, or exagerating a claim), but in practice understanding insurance fraud often requires a much more specific analysis of the claims fraud process. The Taiwan case offers such a possibility, with fraud frequently taking place through the manipulation of the claim's date in order to avoid a penalty from the bonus-malus system and to reduce the burden of a second deductible, should another accident occur.

On the theoretical front, we have analyzed how claim monitoring is affected by the collusion between policyholders and car repairers, how deductible contracts and the specific rules of the Taiwanese bonus-malus regime may be incitements to fraud, and how fraud may induce distortions in the proportions of deductible and no-deductible contracts depending on the distribution channel. On the empirical front, we have established that the intertemporal manipulation of claims was actually a significant determinant of insurance fraud in Taiwan. In particular, we have shown that policyholders with deductible contracts who intend to renew their policies (the suspicious group) have a larger propensity to defraud than other policyholders, by postponing their claims until the last month of the policy year, and possibly by merging two events into a single claim. Consequently, there is an increase in the average cost of first claims filed by the suspicious group in the last month of the policy year. We have also shown that the collusion between policyholders and DOAs is a crucial mechanism that contributes to the development of fraud in the Taiwanese car insurance market. Finally, we have also shown that such mechanisms induce a distortion toward a lower proportion of deductible contracts among the DOAs' customers than among individuals who purchase insurance through other distribution channels.

Our analysis has made progress toward a more complete analysis of claims fraud behavior, but it also opens new perspectives for further research. The theoretical modelling could be refined, for instance, by considering a more realistic set of possible losses (say a continuum instead of two levels) or by analyzing the intertemporal distribution of claims in a more satisfactory way than considering each subperiod (suspicious and non-suspicious) as a whole. It would also be of great interest to analyze the insurer-car repairer vertical relationship (including vertical integration) which would be the most efficient when there is a risk of fraud and collusion. Finally, insurance fraud is just one case where collusion induces additional transaction costs in the vertical relationships between producers and retailers. Other examples include discount fraud and warranty fraud. More theoretical and empirical research is required to evaluate the costs associated with such fraudulent behaviors, and to better understand how they can be detected and prevented most efficiently.

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Appendix 1

Proof of Proposition 1

If $\beta_{ih} > \beta_{ih}^*$, then the optimal choice of the policyholder is $\alpha_{ih} = 0 < \alpha_{ih}^*$, which gives $\beta_{ih} = 0$ for the optimal choice of the insurer, hence a contradiction. Symmetrically, if $\beta_{ih} < \beta_{ih}^*$, then the optimal choice of the policyholder is $\alpha_{ih} = 1 > \alpha_{ih}^*$, which gives $\beta_{ih} = 1$ for the optimal choice of the insurer, hence once again a contradiction. Thus we necessarily have $\beta_{ih} = \beta_{ih}^* \in (0,1)$ at equilibrium. $\beta_{ih} = \beta_{ih}^*$ is an optimal choice of the insurer if

$\alpha_{ih} = \alpha^*_{ih}$. Symmetrically, $\alpha_{ih} = \alpha^*_{ih} \in (0,1)$ is an optimal choice of the policyholder if $\beta_{ih} = \beta^*_{ih}$. Thus $\alpha_{ih} = \alpha^*_{ih}, \beta_{ih} = \beta^*_{ih}$ is the unique equilibrium.

Proof of Proposition 2

Let the expected utility of type $h = 1,2$ policyholders who purchase insurance through $i = A, D$ be written as $\widetilde{u}_{ih}(d) \equiv \overline{u}_h(\Phi(d, \alpha^*(d, c_i)), d)$, where $\Phi(.)$ and $\alpha^*(.)$ are defined by

$$\begin{aligned}\Phi(d,\alpha) &= (1+\sigma)[\overline{L} - (\pi_1 + 2\pi_2)d + k_0(d+k_1)\alpha],\\ \alpha^*(d,c) &= Kc(2\ell - d + v - c)^{-1},\end{aligned}$$

with $K \equiv q_s(\pi_1+\pi_2)/\pi_2 q_m^2 \mu(1-\mu)$. Let

$$\widetilde{\Phi}_i(d) \equiv \Phi(d, \alpha^*(d, c_i)).$$

We have

$$\begin{aligned}\widetilde{\Phi}'_i(d) &= (1+\sigma)[-(\pi_1+2\pi_2) + k_0\alpha^*(d,c_i)\\ &\quad +k_0(d+k_1)Kc(2\ell - d + v - c)^{-2}],\\ \widetilde{\Phi}''_i(d) &= 2Kck_0(1+\sigma)(2\ell - d + v - c)^{-3}(2\ell + v - c + k_1) > 0.\end{aligned}$$

Thus, we have

$$\begin{aligned}\widetilde{u}_{ih}(d) &= (1-\pi_1-\pi_2)u_h(w - \widetilde{\Phi}_i(d)) + \pi_1 u_h(w - \widetilde{\Phi}_i(d) - d - \varepsilon)\\ &\quad +\pi_2 u_h(w - \widetilde{\Phi}_i(d) - 2d - 2\varepsilon),\\ \widetilde{u}'_{ih}(d) &= -(1-\pi_1-\pi_2)u'_h(w - \widetilde{\Phi}_i(d))\widetilde{\Phi}'_i(d)\\ &\quad -\pi_1 u'_h(w - \widetilde{\Phi}_i(d) - d - \varepsilon)(1 + \widetilde{\Phi}'_i(d))\\ &\quad -\pi_2 u'_h(w - \widetilde{\Phi}_i(d) - 2d - 2\varepsilon)(2 + \widetilde{\Phi}'_i(d)).\end{aligned}$$

Using $\widetilde{\Phi}''_i(d) > 0$ and $u''_h < 0$ shows that $\widetilde{u}_{ih}(d)$ is a concave function. Let d_{ih} be the optimal deductible for type h individuals, i.e., d_{ih} maximizes $\widetilde{u}_{ih}(d)$ with respect to $d \geq 0$. Assume first that $d_{i1} > 0$, which implies $\widetilde{u}'_{i1}(d_{i1}) = 0$ and $\widetilde{\Phi}'_i(d_{i1}) < 0$. We have

$$\begin{aligned}\widetilde{u}'_{i2}(d_{i1}) &= -(1-\pi_1-\pi_2)u'_2(w-\widetilde{\Phi}_i(d_{i1}))\widetilde{\Phi}'_i(d_{i1}) \\ &\quad -\pi_1 u'_2(w-\widetilde{\Phi}_i(d_{i1})-d_{i1}-\varepsilon)(1+\widetilde{\Phi}'_i(d_{i1})) \\ &\quad -\pi_2 u'_2(w-\widetilde{\Phi}_i(d_{i1})-2d_{i1}-2\varepsilon)(2+\widetilde{\Phi}'_i(d_{i1})).\end{aligned}$$

Since type 2 individuals are more risk averse than type 1 individuals, we know from Pratt (1964) that there exists a function $g : \mathbb{R} \longrightarrow \mathbb{R}$ such that $u_2(y) \equiv g(u_1(y))$, with $g' > 0$ and $g'' < 0$. This allows us to write

$$\begin{aligned}\widetilde{u}'_{i2}(d_{i1}) &= -(1-\pi_1-\pi_2)g'(u_1(y_0))u'_1(y_0)\widetilde{\Phi}'_i(d_{i1}) \\ &\quad -\pi_1 g'(u_1(y_1))u'_1(y_1)(1+\widetilde{\Phi}'_i(d_{i1})) \\ &\quad -\pi_2 g'(u_2(y_2))u'_1(y_2)(2+\widetilde{\Phi}'_i(d_{i1})),\end{aligned}$$

where $y_0 = w - \widetilde{\Phi}_i(d_{i1}), y_1 = w - \widetilde{\Phi}_i(d_{i1}) - d_{i1} - \varepsilon$ and $y_2 = w - \widetilde{\Phi}_i(d_{i1}) - 2d_{i1} - 2\varepsilon$, with $y_2 < y_1 < y_0$. Let us first consider the case where $1 + \widetilde{\Phi}'_i(d_{i1}) > 0$. Let $y^* \in (y_1, y_0)$. Using $g'' < 0$ and $u'_1 > 0$ yields

$$g'(u_1(y_0)) < g'(u_1(y^*)) < g'(u_1(y_1)) < g'(u_1(y_2)).$$

Using $\widetilde{\Phi}'_i(d_{i1}) < 0 < 1 + \widetilde{\Phi}'_i(d_{i1})$ then gives

$$\widetilde{u}'_{i2}(d_{i1}) < g'(u_1(y^*))\widetilde{u}'_{i1}(d_{i1}) = 0,$$

which implies $d_{i2} < d_{i1}$ because of the concavity of $\widetilde{u}_{i2}(d)$. Similarly, when $1+\widetilde{\Phi}'_i(d_{i1}) < 0 < 2 + \widetilde{\Phi}'_i(d_{i1})$, we let $y^* \in (y_2, y_1)$ and a similar argument also yields $d_{i2} < d_{i1}$. Similarly, if $d_{i1} = 0$, we have $\widetilde{u}'_{i1}(0) \leq 0$, and the same argument gives $\widetilde{u}'_{i2}(0) < 0$ and thus $d_{i2} = 0$.

Example with mean-variance preferences

The case $d_{i1} > 0, d_{i2} = 0$ can be conveniently illustrated by a mean-variance example. Assume that $u_1(w_f)$ and $u_2(w_f)$ are quadratic, so that we may write

$$u_h(w_f) = E(w_f) - \eta_h Var(w_f),$$

with $\eta_2 > \eta_1$. When insurance is purchased through distribution channel i, we have

$$
\begin{aligned}
E(w_f) &= w - \widetilde{\Phi}_i'(d) - (\pi_1 + 2\pi_2)(d + \varepsilon), \\
Var(w_f) &= I(d + \varepsilon)^2,
\end{aligned}
$$

with $I = \pi_1(1 - \pi_1) + 4\pi_2(1 - \pi_1 - \pi_2) > 0$. We have $d_{ih} > 0$ iff

$$
-\widetilde{\Phi}_i'(0) - (\pi_1 + 2\pi_2) - 2\eta_h I\varepsilon^2 > 0,
$$

and thus we have $d_{i1} > 0, d_{i2} = 0$ if

$$
\eta_1 < \eta^* < \eta_2,
$$

where

$$
\begin{aligned}
\eta^* = & \frac{1}{2I\varepsilon^2} \times [\sigma(\pi_1 + 2\pi_2) \\
& -(1 + \sigma)k_0 Kc(2\ell + v - c)^{-2}(2\ell + v - c + k_1)].
\end{aligned}
$$

Proof of Proposition 3

Let

$$
\overline{u}_h(\Phi(d, \alpha), d) \equiv \Gamma_h(d, \alpha).
$$

Let us write the equilibrium fraud rate as

$$
\alpha^*(d, c) = Kc(2\ell - d + v - c)^{-1},
$$

with $K \equiv q_s(\pi_1 + \pi_2)/\pi_2 q_m^2 \mu(1 - \mu)$. Assume $\overline{u}_h(\Phi(d, \alpha^*(d, c)), d) = \Gamma_h(d, \alpha^*(d, c))$ is maximized w.r.t. d at $d = \widehat{d}_h(c)$ with fraud rate $\widehat{\alpha}_h(c) \equiv \alpha^*(\widehat{d}_h(c), c)$. Thus, we have $\alpha_{ih} = \widehat{\alpha}_h(c_i) \equiv \alpha^*(\widehat{d}_h(c_i), c_i)$ for $i \in \{A, D\}$. The first-order and second-order optimality conditions for this maximization are respectively written as

$$
F_h \equiv \Gamma_{hd}' + \Gamma_{h\alpha}' \frac{\partial \alpha^*}{\partial d} = 0, \tag{19}
$$

and

$$S_h \equiv \Gamma''_{hd^2} + \Gamma''_{hd\alpha}\frac{\partial\alpha^*}{\partial d} + \Gamma''_{h\alpha^2}\left(\frac{\partial\alpha^*}{\partial d}\right)^2 + \Gamma'_{h\alpha}\frac{\partial^2\alpha^*}{\partial d^2} < 0, \tag{20}$$

where $\Gamma'_{hd}, \Gamma'_{h\alpha}, \Gamma''_{hd^2}, \Gamma''_{hd\alpha}, \Gamma''_{h\alpha^2}$ denote first and second derivatives of Γ_h and all functions are evaluted at $d = \widehat{d}_h(c)$. Differentiating (19) gives

$$\widehat{d}'_h(c) = -\frac{F'_{hc}}{S_h},$$

where

$$F'_{hc} = \frac{\partial F_h}{\partial c} = \Gamma''_{hd\alpha}\frac{\partial\alpha^*}{\partial c} + \Gamma''_{h\alpha^2}\frac{\partial\alpha^*}{\partial c}\frac{\partial\alpha^*}{\partial d} + \Gamma'_{h\alpha}\frac{\partial^2\alpha^*}{\partial d\partial c}.$$

After simplication we get

$$\begin{aligned}
\widehat{\alpha}'_h(c) &= \frac{\partial\alpha^*}{\partial d}\widehat{d}'_h(c) + \frac{\partial\alpha^*}{\partial c} \\
&= (1/S_h)\left\{\Gamma'_{h\alpha}\left[\frac{\partial^2\alpha^*}{\partial d^2}\frac{\partial\alpha^*}{\partial c} - \frac{\partial^2\alpha^*}{\partial d\partial c}\frac{\partial\alpha^*}{\partial d}\right] + \Gamma''_{hd^2}\frac{\partial\alpha^*}{\partial c}\right\}.
\end{aligned} \tag{21}$$

We have

$$\begin{aligned}
\frac{\partial\alpha^*}{\partial d} &= Kc(2\ell - d - c)^{-2}, \\
\frac{\partial\alpha^*}{\partial c} &= K(2\ell - d - c)^{-1} + Kc(2\ell - d - c)^{-2}, \\
\frac{\partial^2\alpha^*}{\partial d^2} &= 2Kc(2\ell - d - c)^{-3}, \\
\frac{\partial^2\alpha^*}{\partial d\partial c} &= K(2\ell - d - c)^{-2} + 2Kc(2\ell - d - c)^{-3}.
\end{aligned}$$

Hence

$$\frac{\partial^2\alpha^*}{\partial d^2}\frac{\partial\alpha^*}{\partial c} - \frac{\partial^2\alpha^*}{\partial d\partial c}\frac{\partial\alpha^*}{\partial d} = K^2c(2\ell - d - c)^{-4} > 0.$$

Furthermore,

$$\begin{aligned}
\Gamma_h(d,\alpha) &= (1 - \pi_1 - \pi_2)u_h(w - \Phi(d,\alpha)) \\
&\quad + \pi_1 u_h(w - \Phi(d,\alpha) - d) + \pi_2 u_h(w - \Phi(d,\alpha) - 2d).
\end{aligned}$$

$\Phi(d,\alpha)$ is linear in d, and thus $\Gamma_h(d,\alpha)$ is concave in d, which implies $\Gamma''_{hd^2} < 0$. We also have

$$\Gamma'_{h\alpha} = \frac{\partial \overline{u}_h}{\partial P}\frac{\partial \Phi}{\partial \alpha} < 0.$$

Using (21) and $\Gamma'_{h\alpha} < 0, \Gamma''_{hd^2} < 0, \partial\alpha^*/\partial c > 0$ then yields $\widehat{\alpha}'_h(c) > 0$. Thus, we have $\alpha_{D1} = \widehat{\alpha}(c_D) > \widehat{\alpha}(c_A) = \alpha_{A1}$.[47]

[47]Note that if transaction costs prevent insurers from offering contracts with deductibles that depend on the distribution channel, i.e., if we assume $d_{A1} = d_{D1} \equiv d_1$, then the fraud rates are $\alpha_{D1} = \alpha^*(d_1, c_D) > \alpha^*(d_1, c_A) = \alpha_{A1}$, and the proposition is obviously still valid.

Appendix 2

In this appendix, we show how the bargaining power of the policyholder-repairer coalition affects the scale of fraud. The bargaining power of the colluders is taken into account in a very crude way by assuming that the defrauders will not be punished with probability $\xi_i \in (0,1)$, with $i = D$ or A. Intuitively, the insurance agent is incentivized to stand up for its customer (and possibly also for the repairer in the case of a DOA that owns the repair shop), and it may threaten the insurer to redirect its customers toward another insurer. This may deter the insurer from enforcing the penalty. A larger bargaining power for D than for A corresponds to $\xi_D > \xi_A$. Thus, if the colluders are spotted (which occurs if the claim is audited), then with probability $1-\xi_i$ the penalties are enforced (no indemnity is paid by the insurer and the colluders pay the fines B and B', respectively, and with probability ξ_i the insurer interprets the fraud as an involuntary error, i.e., the policyholder receives the total cumulated contractual indemnity $2(\ell - d_{ih})$ and no fines are paid. Under these assumptions, a type h policyholder with two minor accidents and a repairer are willing to defraud (with the policyholder making a side-payment G to the repairer on a take-it-or-leave-it basis) if

$$Eu^F_{ih} \geq Eu^N_{ih} \tag{22}$$

and

$$G - \beta_{ih}(1-\xi_i)B' \geq 0, \tag{23}$$

respectively, with

$$\begin{aligned} Eu^F_{ih} \;=\; & q_m\mu\widehat{\pi}[(1-\beta_{ih})u_h(w - P_{ih} - d_{ih} - 2\varepsilon + v - G) \\ & +\beta_{ih}(1-\xi_i)u_h(w - P_{ih} - 2\ell - 2\varepsilon - G - B) + \beta_{ih}\xi_i u_h(w - P_{ih} - 2d_{ih} - G)] \\ & +(1 - q_m\mu\widehat{\pi})[\widehat{\pi}u_h(w - P_{ih} - \ell - d_{ih} - 2\varepsilon) + (1-\widehat{\pi})u_h(w - P_{ih} - \ell - \varepsilon)]. \end{aligned}$$

Fraud is deterred (i.e., $\alpha_{ih} = 0$) if $\beta_{ih} > \beta^{**}_{ih}$ where $\beta^{**}_{ih}(P_{i1}, d_{ih}, \xi_i)$ is the value of β_{ih}

such that

$$Eu_{ih}^F = Eu_{ih}^N \text{ with } G = \beta_{ih}(1-\xi_i)B'.$$

Since defrauders who are caught are not punished with probability ξ_i, the expected actuarial cost of a deductible insurance policy is now written as

$$\begin{aligned} FC_{ih} &= \delta q_m \alpha_{ih}(\pi_1+\pi_2)(1-\mu) \\ &\quad \times\{q_m\mu\widehat{\pi}[(1-\beta_{ih})(d_{ih}+v) - 2\beta_{ih}(1-\xi_i)(\ell - d_{ih})] \\ &\quad -(1-q_m\mu\widehat{\pi})(\ell-d_{ih})\}. \end{aligned} \tag{24}$$

The equilibrium audit and fraud strategies are $\alpha_{ih} = \alpha^{**}(d_{ih}, c_i, \xi_i)$ and $\beta_{ih} = \beta_{ih}^{**}(P_{ih}, d_{ih}, \xi_i)$, with

$$\alpha_{ih}^{**}(d_{ih}, c_i, \xi_i) \equiv \frac{q_s c_i(\pi_1+\pi_2)}{\pi_2 q_m^2 \mu(1-\mu)[(1-\xi)(2\ell - d_{ih}) + \xi_i d + v - c_i)}, \tag{25}$$

which can be interpreted in the same way as (5) in Section 3.4 and extends Proposition 1 in a straightforward way. The equilibrium contract (P_{ih}, d_{ih}) maximizes $\overline{u}_h(P,d)$ subject to $P = \Phi(d, \alpha^{**}(d, c_i, \xi_i))$, and the equilibrium fraud rates are $\alpha_{ih} = \alpha^{**}(d_{ih}, c_i, \xi_i)$ for $i = A$ or D. In the same way as in the proof of Proposition 3, we can then show that $\alpha_{Dh} > \alpha_{Ah}$ if $c_D = c_A$ and $\xi_D > \xi_A$. To establish this result, we make the additional assumption $\xi_D < 1/2$.[48] The definition of $\Phi(d,\alpha)$ is unchanged, and we still denote $\Gamma_h(d,\alpha) \equiv \overline{u}_h(\Phi(d,\alpha), d)$.

$\Gamma_h(d, \alpha^{**}(d,c,\xi))$ is maximized w.r.t. d at $d = \widetilde{d}_h(c,\xi)$ with fraud rate $\widetilde{\alpha}_h(c,\xi) \equiv \alpha^{**}(\widetilde{d}_h(c,\xi), c, \xi)$. The equilibrium fraud rates are $\alpha_{ih} = \widetilde{\alpha}_h(c_i,\xi_i) \equiv \alpha^{**}(\widetilde{d}_h(c_i,\xi_i), c_i, \xi_i)$ for $i \in \{A, D\}$. We have (similarly to the proof of Proposition 3, with an unchanged definition for S_h):

[48] For a given fraud rate α_{ih}, the decrease in actuarial cost $\mathrm{d}C_{ih} < 0$ induced by a small increase in the audit probability $\mathrm{d}\beta_{ih} > 0$ is $\mathrm{d}C_{ih} = -\eta q_m^2 \alpha_{ih}[d_{ih} + 2(1-\xi_i)(\ell - d_{ih})]\mathrm{d}\beta_{ih}$. We consider the case where the decrease in cost is larger when the deductible is lower, which requires $\xi_i < 1/2$.

$$
\begin{aligned}
\frac{\partial \widetilde{\alpha}(c,\xi)}{\partial \xi} &= \frac{\partial \alpha^{**}}{\partial d}\frac{\partial \widetilde{d}_h(c,\xi)}{\partial \xi} + \frac{\partial \alpha^{**}}{\partial \xi} \\
&= (1/S_h)\left\{\Gamma'_{h\alpha}\left[\frac{\partial^2 \alpha^{**}}{\partial d^2}\frac{\partial \alpha^{**}}{\partial \xi} - \frac{\partial^2 \alpha^{**}}{\partial d \partial \xi}\frac{\partial \alpha^{**}}{\partial d}\right] + \Gamma''_{hd^2}\frac{\partial \alpha^{**}}{\partial \xi}\right\}. \qquad (26)
\end{aligned}
$$

We have $\alpha^{**}(d,c,\xi) = Kc[(1-\xi)(2\ell - d) + \xi d + v - c]^{-1}$, and thus

$$
\begin{aligned}
\frac{\partial \alpha^{**}}{\partial d} &= Kc(1-2\xi)[(1-\xi)(2\ell-d)+\xi d+v-c]^{-2}, \\
\frac{\partial \alpha^{**}}{\partial \xi} &= 2Kc(\ell-d)[(1-\xi)(2\ell-d)+\xi d+v-c]^{-2}, \\
\frac{\partial^2 \alpha^{**}}{\partial d^2} &= -2Kc(1-2\xi)^2[(1-\xi)(2\ell-d)+\xi d+v-c]^{-3}, \\
\frac{\partial^2 \alpha^{**}}{\partial d \partial \xi} &= -2Kc[(1-\xi)(2\ell-d)+\xi d+v-c]^{-2} - 4Kc(1-2\xi)(\ell-d)[(1-\xi)(2\ell-d)+\xi d+v-c]^{-3}.
\end{aligned}
$$

Hence,

$$
\frac{\partial^2 \alpha^{**}}{\partial d^2}\frac{\partial \alpha^{**}}{\partial \xi} - \frac{\partial^2 \alpha^{**}}{\partial d \partial \xi}\frac{\partial \alpha^{**}}{\partial d} = 2K^2c^2(1-2\xi)[(1-\xi)(2\ell-d)+\xi d-c]^{-4} > 0. \qquad (27)
$$

Using $S_h < 0, \Gamma'_{h\alpha} < 0, \Gamma''_{hd^2} < 0, \partial\alpha^{**}/\partial\xi > 0$, (26) and (27) yields $\partial\widetilde{\alpha}(c,\xi)/\partial\xi > 0$. Thus, we have $\alpha_{Dh} = \widetilde{\alpha}(c,\xi_D) > \widetilde{\alpha}(c,\xi_A) = \alpha_{A1}$ when $c_D = c_A = c$ and $\xi_D > \xi_A$.

Appendix 3

(Insert Table 8 here)

As shown in Table A1, the p-values of the Anderson-Rubin test in the two first-stage LPMs are 0.4732 and 0.3820, respectively, and the null hypothesis of the exogenous instrumental variable cannot be rejected. Secondly, the p-values of the J test in these two LPMs are 0.3066 and 0.1591, and we cannot reject the null hypothesis that the instruments are not over identified either. Thirdly, the p-values of the Durbin-Wu-Hausman test in these two LPMs are 0.0220 and 0.0420, respectively, and we can reject the null hypothesis that the instrumental variable method is irrelevant at the 5% level for each instrumented variable. All in all, this confirms the properness of our IV approach. Table A1 also yields some by-products: policyholders living in high income areas and in areas with a high density of DOAs significantly tend to renew their contracts and to choose policies with deductibles, which is consistent with the results obtained in the 2SLS approach.

The second stage regressions show that filing a suspicious claim and continuing the contract (or choosing a deductible contract) are conditionally dependent decisions, with a positive significant dependence. The estimated coefficient of $\Pr(SG)$ is 1.5457, and it is significantly different from 0 at the 1% level. The estimated coefficient of $\Pr(deduct)$ is 1.2647, and it is also significantly different from 0 at the 1% level, which indicates that policyholders who renew their contracts and have chosen a deductible contract have a larger propensity to file claims during the suspicious period.

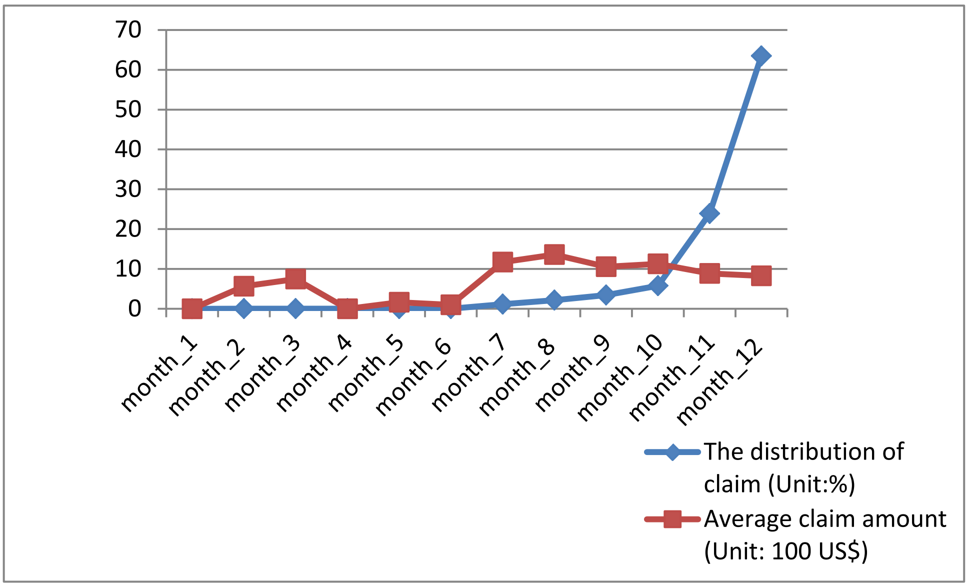

Figure 1: Distribution of claims and average claim cost (first claims) in the policy year

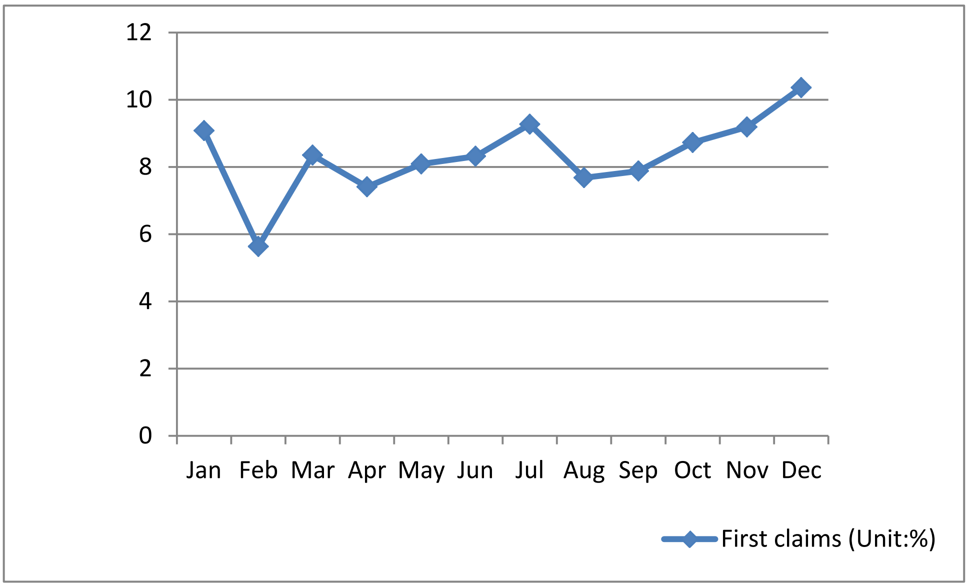

Figure 2: Distribution of the first claims in the calendar year

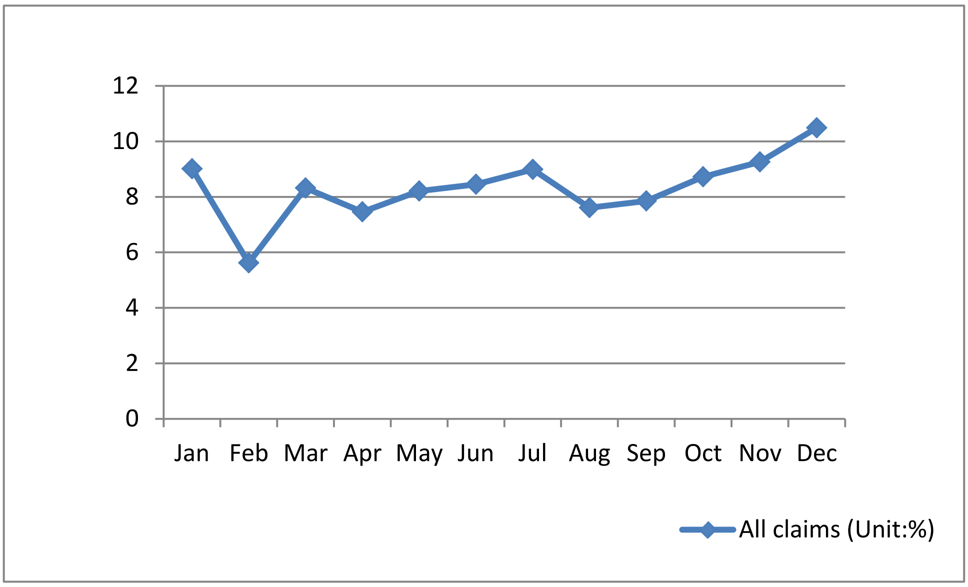

Figure 3: Distribution of all claims in the calendar year

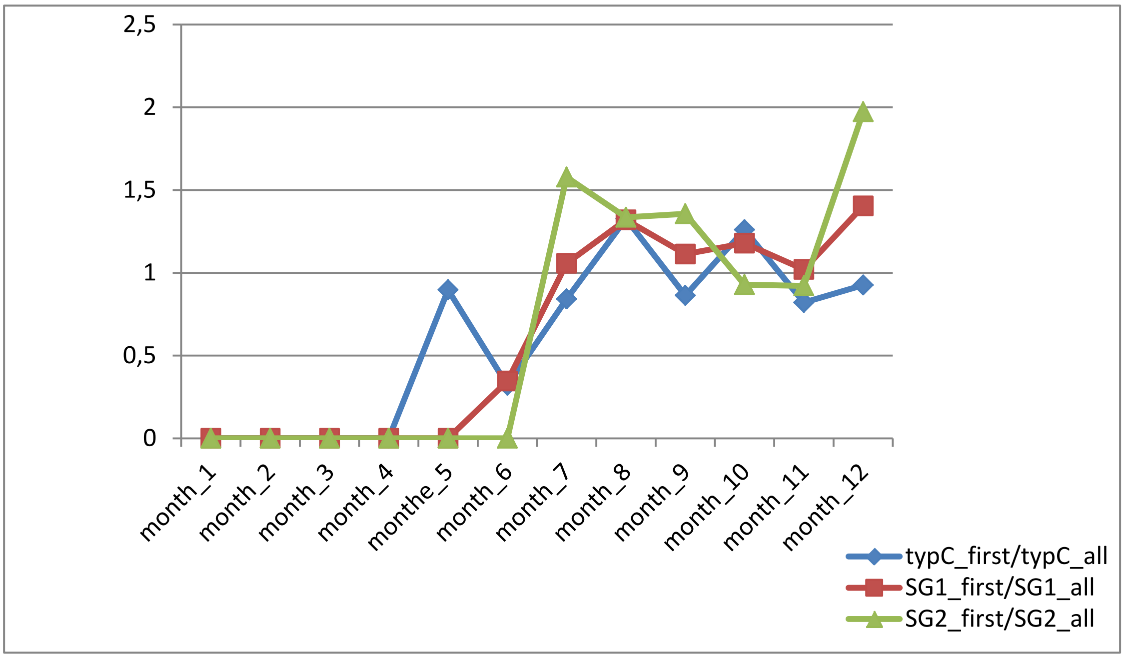

Figure 4: Average cost of first claims / Average cost of all claims
Comparing the suspicious group and type C contracts

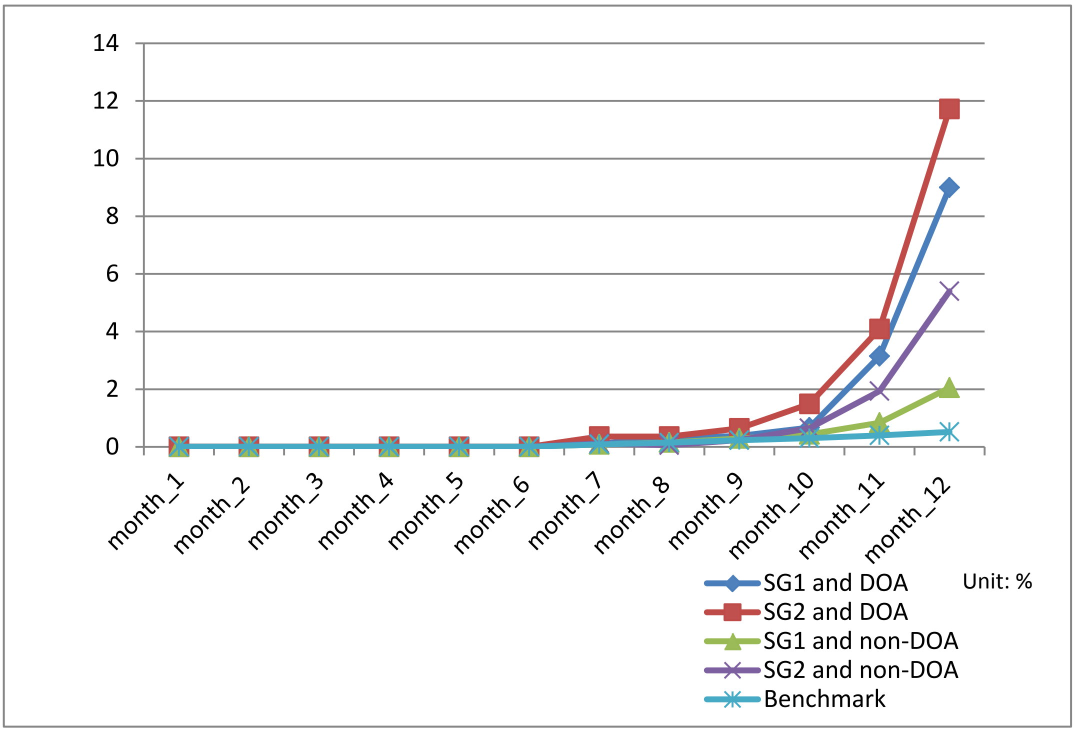

Figure 5: Distribution of claims in the policy year

Table 1:

Definition of variables

Variable	Definition
Explained variable:	
SG	Dummy variable equal to 1 when the insured belongs to the "suspicious group",[1] and 0 otherwise.
SG1	Dummy variable equal to 1 when the insured belongs to "suspicious group 1",[2] and 0 otherwise.
SG2	Dummy variable equal to 1 when the insured belongs to "suspicious group 2",[3] and 0 otherwise.
nodedt	Dummy variable equal to 1 when the insured has taken out a no-deductible contract, and 0 otherwise.
SC	Dummy variable equal to 1 when the insured has filed his or her first claim during the suspicious period (in the last policy month), 0 otherwise.
Explanatory variables: First group (underwriting and pricing factors)	
female	Dummy variable equal to 1 if the insured is a female, 0 otherwise.
age2025	Dummy variable equal to 1 if the insured is in the 20-25 age group, 0 otherwise.
age2530	Dummy variable equal to 1 if the insured is in the 25-30 age group, 0 otherwise .
age3060	Dummy variable equal to 1 if the insured is in the 30-60 age group, 0 otherwise.
ageabv60	Dummy variable equal to 1 if the insured is older than 60, 0 otherwise.
carage0	Dummy variable equal to 1 when the car is less than one year old, 0 otherwise.
carage1	Dummy variable equal to 1 when the car is two years old, 0 otherwise.
carage2	Dummy variable equal to 1 when the car is three years old, 0 otherwise.
carage3	Dummy variable equal to 1 when the car is four years old, 0 otherwise.
carage4	Dummy variable equal to 1 when the car is more than four years old, 0 otherwise.
veh_m	Dummy variable equal to 1 when the capacity of the insured car is between 1800 and 2000 c.c., 0 otherwise.
veh_l	Dummy variable equal to 1 when the capacity of the insured car is larger than 2000, 0 otherwise.

[1] The "suspicious group" (*SG*) includes the individuals who renew their contract with the same insurance company. The counter group for SG includes the policyholders who do not renew their contract with the same insurance company.

[2] The "suspicious group 1" (*SG*1) includes the policyholders with no-deductible contract who renew their contract with the same insurance company. The counter group for SG1 includes the policyholders with deductible contract or who do not renew their contract with the same insurance company.

[3] The "suspicious group 2" (*SG*2) includes the policyholders with deductible contract who renew their contract with the same insurance company. The counter group for SG2 includes the policyholders with no-deductible contract or who do not renew their contract with the same insurance company.

tramak_j	Dummy variable equal to 1 when the brand of the insured car is *j*, with *j*=*n*, *f*, *h*, *t*, *c*, and 0 otherwise.[4]
sedan	Dummy variable equal to 1 when the car is a sedan and is for non-commercial or for long-term rental purposes, and 0 otherwise.[5]
logprem	Logarithm of the premium of the contract in the current contract year.
bonus	Bonus-malus coefficient used to calculate the premium in the current contract year. It is a multiplier on the premium. Hence, it is a discount if it is smaller than 1 and it is a penalty if it is larger than 1.

Explanatory variables (Second group):

income	Dummy variable equal to 1 if the insured lives in an area with average income in the top 25% tranche, and 0 otherwise.
dealer	Dummy variable equal to 1 if the insured lives in an area with DOA density in the top 25% tranche, and 0 otherwise.
new	Dummy variable equal to 1 when the insured car is less or equal to three year old, and 0 otherwise.
logprem	Logarithm of the premium of the contract in the current contract year.
D	Dummy variable equal to 1 if the insurance contract is sold through the DOA channel, and 0 otherwise.
A	Dummy variable equal to 1if the insured is covered by a type A contract, and 0 otherwise.
B	Dummy variable equal to 1 when the insured is covered by a type B contract, and 0 otherwise.[6]
RG	Dummy variable equal to 1 when the insured belongs to the “recoup group”,[7] and 0 otherwise.

[4] The insured cars in counter group for *tramak_j*, *j*= *n*, *f*, *h*, *t*, *c* , are other brands (other than Nissan, Ford, Honda, Toyota, and China.)

[5] The counter group includes the insured cars are not small sedan, for example small or large truck, cargo…etc.

[6] The contracts in the counter groups for *A* and *B* are type C contracts.

[7] The “recoup group” includes the policyholders covered by type A or B contracts who do not renew their contract or renew it for only one year.

Table 2-1:

Structure of the full sample and of the sub-sample with claims

	Full sample (1)	Sub-sample with claims (2)	Difference (2)-(1)
claim	0.1033		
SC		0.6468	
RG	0.1980	0.3942	0.1962***
nodedt	0.9514	0.9317	-0.0167***
A	0.0103	0.0140	0.0037***
B	0.3882	0.8876	0.4994***
SG	0.7179	0.7226	-0.1262***
SG1	0.6894	0.6658	-0.0236***
SG2	0.0285	0.0568	0.0283***
D	0.5078	0.7998	0.2920***
female	0.7118	0.7600	0.0482***
age2025	0.0032	0.0028	-0.0004
age2530	0.0342	0.0464	0.0122
age3060	0.8947	0.8929	-0.0018
ageabv60	0.0679	0.0579	-0.0100
carage0	0.2192	0.5116	0.2924***
carage1	0.1381	0.2023	0.0705***
carage2	0.0915	0.0642	-0.0273***
carage3	0.1109	0.0665	-0.0444***
carage4	0.0986	0.0438	-0.0548***
veh_m	0.2875	0.2256	-0.0619***
veh_l	0.2692	0.2696	0.0004
tramak_n	0.0069	0.0057	-0.0012
tramak_f	0.0609	0.0586	-0.0552
tramak_h	0.0805	0.0531	-0.0274
tramak_t	0.4692	0.6262	0.1570***
tramak_c	0.0415	0.0120	-0.0295
sedan	0.9166	0.9398	0.0232
logprem	9.2346	10.0632	0.8286***
bonus	0.7180	0.8773	0.1593***
No of obs.	109,461	11,248	

Table 2-2:

Structure of the DOA and non-DOA subsamples

	DOA (1)	**Non-DOA** (2)	**Difference** (1)-(2)
SC	0.6719	0.5466	0.1253***
RG	0.3428	0.5992	-0.2564***
nodedt	0.9363	0.9134	0.0229***
A	0.0118	0.0226	-0.0226***
B	0.9345	0.7003	0.2342***
SG	0.7664	0.5479	0.2185***
SG1	0.7029	0.5178	0.1851***
SG2	0.0635	0.0301	0.0334***
female	0.7698	0.7207	0.0491***
age2025	0.0027	0.0036	-0.0009
age2530	0.0472	0.0431	0.0041
age3060	0.8938	0.8890	0.0048
ageabv60	0.0562	0.0644	-0.0082
carage0	0.5953	0.1776	0.4177***
carage1	0.2000	0.2118	-0.0118
carage2	0.0581	0.0884	-0.0303***
carage3	0.0517	0.1257	0.0740***
carage4	0.0326	0.0888	-0.0562***
veh_m	0.2093	0.2904	-0.0811***
veh_l	0.2621	0.2993	-0.0372***
tramak_n	0.0043	0.0111	-0.0068***
tramak_f	0.0485	0.0990	-0.0505***
tramak_h	0.0411	0.1008	-0.0597***
tramak_t	0.6962	0.3464	0.3498***
tramak_c	0.0026	0.0497	-0.0471***
sedan	0.9532	0.8863	0.0669***
logprem	10.1650	9.6565	0.5085
bonus	0.9110	0.7426	0.1684***
No of obs.	8,996	2,252	

Table 3:

Empirical evidence of fraud

	First stage (bivariate Probit)		Second stage	
	SG	***deduct***	***2SLS-Probit***	***DGV-Probit***
constant	1.4264***	-1.7669***	0.2160	0.0735
Pr(*SG*1)			1.5688***	1.0427***
Pr(*SG*2)			2.0479***	1.7074***
***SG*1**				0.3164**
***SG*2**				0.4836***
income	-0.0752**	0.3093***		
dealer	0.0161***	-0.1339***		
RG	-2.0748***	0.3028***	1.0057***	0.1517***
female	0.0941***	-0.1455***	0.0847***	0.0821***
age2530	0.2405	0.3783	-0.2256	-0.2375
age3060	0.2930	0.1659	-0.1790	-0.1920
ageabv60	0.0973	0.1112	-0.3126	-0.3187
carage0	0.4225***	0.0570**	0.2332***	0.2513***
carage1	0.1009*	0.0440*	0.1966***	0.1944***
carage2	0.1192	-0.0603	0.2427***	0.2404***
carage3	0.1052	-0.0768	0.2076***	0.2067***
carage4	0.0425	-0.0313	0.0552	0.0555
veh_m	0.0127	0.0147	-0.0097	-0.0100
veh_l	0.1046***	0.2310***	-0.0557*	-0.0605*
sedan	-0.0350	0.2751***	-0.0201	-0.0200
Pseudo R^2	0.0542		0.0451	0.0465

Notes

(1) In the above models Pr($SG1_i$) and Pr($SG2_i$) are the estimated probabilities of belonging to the suspicious groups *SG*1 and *SG*2, respectively, calculated at the first stage, that is Pr($SG1_i$)= Pr(SG_i=1, $deduct_i$=0), and Pr($SG2_i$) = Pr(SG_i=1, $deduct_i$=1). In the DGV-Probit model, *SG*1 and *SG*2 are dummy variables equal to 1 if the policyholder belongs to the suspicious groups *SG*1 and *SG*2, respectively, and 0 otherwise.

(2) In all the above regressions, we have also controlled for the brand of the insured car. This is not reported for reasons of confidentiality.

(3) ***,** and * indicate that the estimated coefficient is significantly different from 0 at the 1%, 5% and 10% level, respectively.

(4) We have also performed two sets of the 2SLS-LPM to confirm the validity of our IV model. In both sets, the null hypothesis of irrelevant model is rejected by the Durbin-Wu-Hausman test, the null hypothesis of exogenous instrumental variable cannot be rejected by the Anderson-Rubin test, the null hypothesis of no over identification cannot be rejected by the *J* test.

Table 4:

Additional evidence of fraud

	SG1	SG2	non-SG
	Panel A: Predicted errors		
filing a claim	0.1201	0.1213	0.1330
filing SC	0.3072	0.3969	0.2639
t test	-130 (<0.0001)	-170 (<0.0001)	-31.3673 (<0.0001)
	Panel B: Baseline hazard in each policy month		
1^{st} month		-	-
2^{nd} month		-	0.00003
3^{rd} month		-	0.00003
4^{th} month		-	0.00003
5^{th} month		-	0.00003
6^{th} month	0.000002		0.00003
7^{th} month	0.0001	0.0003	0.0015
8^{th} month	0.0021	0.0019	0.0024
9^{th} month	0.0033	0.0042	0.0041
10^{th} month	0.0055	0.0104	0.0069
11^{th} month	0.0191	0.0326	0.0345
12^{th} month	0.0538	0.0874	0.0457

Table 5: Empirical evidence of fraud - Focus on type B contracts

	First stage (bivariate probit)		Second stage	
	SG	***deduct***	***2SLS-Probit***	***DGV-Probit***
constant	1.2881***	-1.8345***	0.7050**	0.6609**
Pr(*SG*1)			1.3076***	1.0288***
Pr(*SG2*)			1.9137***	1.6741***
SG1				0.2407**
SG2				0.3573***
income	-0.0610***	0.3272***		
dealer	0.0172*	-0.0966**		
RG	-2.9190***	0.1962***	1.0022***	0.1487***
female	0.1065***	-0.1667***	0.0828***	0.0822***
age2530	0.3279	0.7018	-0.3714	-0.3701
age3060	0.3536	0.4452	-0.3829	-0.3814
ageabv60	0.0529	0.3848	-0.5057	-0.5007
carage0	0.8014***	-0.0019	0.2920***	0.0150
carage1	0.1876**	-0.0781	0.1607***	0.1603***
carage2	-0.1434	-0.1629	0.1543***	0.1557***
carage3	-0.0972	-0.2115	0.0981	0.0985
carage4	-0.2555	-0.0338	-0.0446	-0.0424
veh_m	0.0339	0.0078	-0.0338	-0.0326
veh_l	0.0642*	0.0351	-0.0951***	-0.0945***
sedan	0.0448	0.1995**	-0.0281	-0.0278
Pseudo R^2	0.0521		0.0352	0.0373

Same notes as in Table 3

Table 6:

Empirical evidence of fraud through DOAs

	First stage	Second stage	
	(Instrument on D)	*2SLS-Probit*	*DGV-Probit*
constant	-0.1944	0.0969	-0.1910
Pr(*SG1*)		0.6843*	0.4762*
Pr(*SG2*)		1.0644**	0.8930***
***SG*1**			0.0845
***SG*2**			0.1930*
Pr(*D*)		1.3660***	1.6798***
Pr(*D*)*Pr(*SG1*)		1.0477***	0.7134***
Pr(*D*)*Pr(*SG2*)		1.1005***	0.9773***
Pr(*D*)*SG1*			0.2881*
Pr(*D*)*SG2*			0.3440**
income	0.3093*		
Dealer	0.2620*		
New	0.5340***		
RG	0.1275***	1.0639**	0.3197*
Pr(*D*)*RG*		-0.0836	-0.2415
Female	0.0268	0.0824**	0.0814**
age2530	0.1329	-0.4295	-0.4267
age3060	0.2840	-0.4573	-0.4583
ageabv60	0.3450	-0.5888*	-0.5892*
carage0	0.8864***	-0.4331***	-0.4375***
carage1	0.3564***	-0.2948***	-0.2953***
carage2	0.2942***	-0.1725*	-0.1704*
carage3	0.1691*	-0.0441	-0.0423
carage4	0.0751	-0.1690*	-0.1642*
veh_m	-0.0172	-0.0343	-0.0370
veh_l	-0.1211***	-0.0689**	-0.0680**
Sedan	0.2634***	-0.1268*	-0.1305*
Pseudo R^2	0.2213	0.0450	0.0560

Same notes as in Table 3

Table 7:

Comparing the policyholders' risk between the DOA and non-DOA channels

Variables	Est. Ceoff.	P value
Intercept	23.2634	0.4353
D	-1.8105	0.3308
A	17.6766	0.0001
B	4.1090	0.0050
D*A	1.7407	0.7093
D*B	1.6078	0.6758
Female	-2.0447	0.0028
age2025	4.0914	0.8924
age2530	1.3474	0.9639
age3060	-5.8571	0.0097
ageabv60	1.4598	0.9609
carage0	0.2970	0.7804
carage1	1.6699	0.1395
carage2	1.4368	0.3232
carage3	3.4444	0.0147
carage4	3.6011	0.0264
veh_m	2.8894	0.0001
veh_l	12.6377	<.0001
sedan	10.6254	<.0001
Adjusted R^2	0.0605	

Note: In the above regression, we have also controlled the brand of the insured car. The results are not reported for reasons of confidentiality.

Table 8:

Empirical results from 2SLS-LM

	2SLS-LPM			
	SG	***SC***	***deduct***	***SC***
constant	0.9114***	9.7965***	0.0654	0.0956
Pr(*SG*)		1.5457***		
Pr(*deduct*)				1.2647***
income	-0.0326*		0.3541***	
dealer	0.0622**		-0.1790***	
RG	-0.6093***	0.1829***	0.0362***	0.1977***
female	0.0213***	0.3130 ***	-0.0183***	0.1126***
age2530	0.0487	0.2796	0.0597	-0.3104
age3060	0.0603	0.4492	0.0308	-0.2286
ageabv60	0.0112	-0.2022	0.0246	-0.3570
carage0	0.1186***	1.0114***	0.0060*	0.2330***
carage1	0.0166	0.3753**	0.0044	0.1922***
carage2	0.0200	0.4569**	0.0070	0.2509***
carage3	0.0144	0.3641**	-0.0096	0.2208***
carage4	-0.0011	0.0441	0.0001	0.0523
veh_m	0.0036	-0.0271	0.0026	-0.0096
veh_l	0.0229***	-0.1785***	0.0244***	-0.0978***
sedan	0.0043	0.0716	0.0371***	0.0798
J test	0.3066		0.1591	
Anderson-Rubin test	0.4732		0.3820	
Durbin-Wu-Hausman test	0.0220		0.0420	
Pseudo/Adjusted R^2	0.4570	0.0510	0.0713	0.0420